

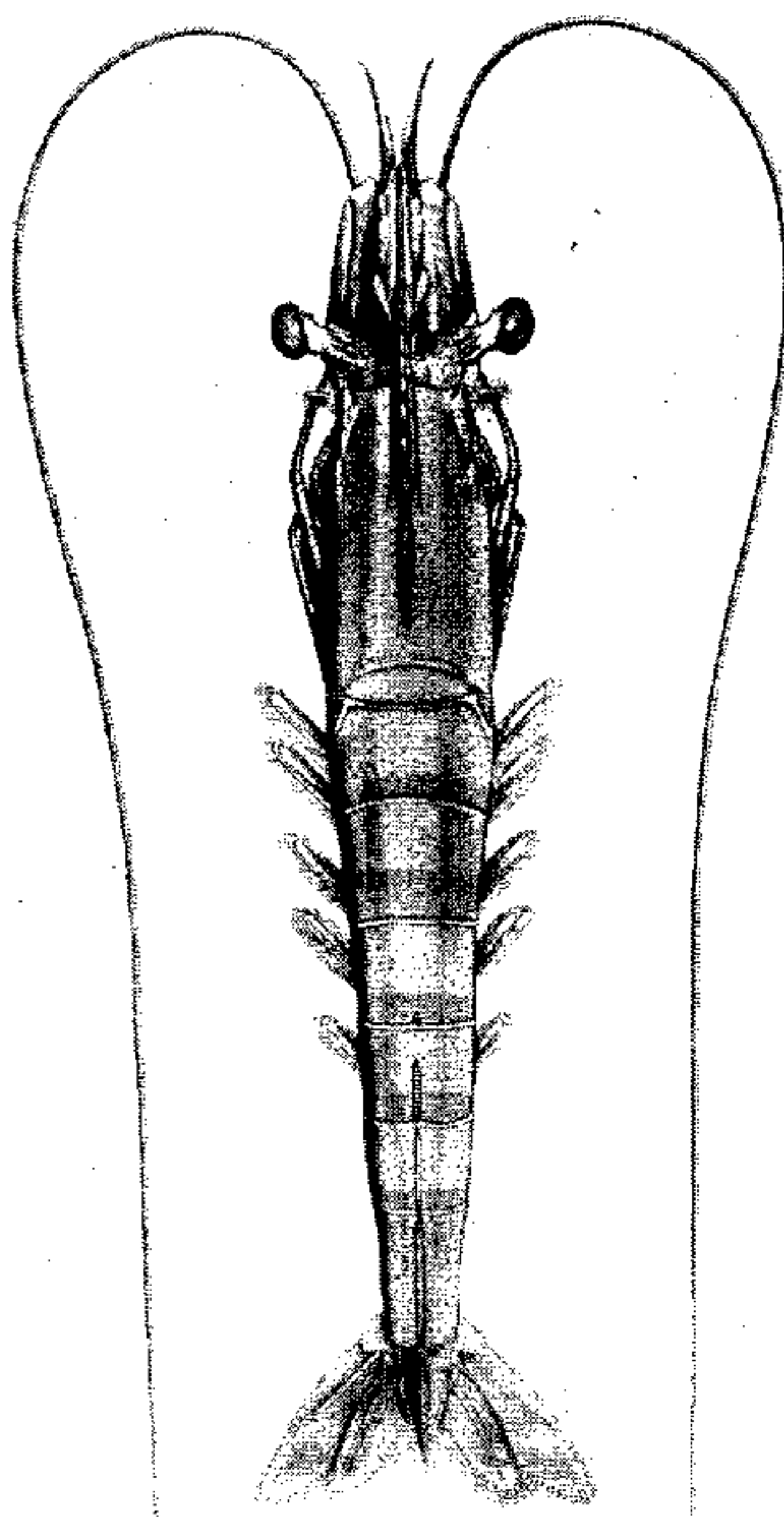
United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner
Bureau of Commercial Fisheries, Donald L. McKernan, Director

GALVESTON BIOLOGICAL LABORATORY

FISHERY RESEARCH

for the year ending June 30, 1960

George A. Rounsefell, Director
Bernard E. Skud, Assistant Director



Circular 92

Washington, D. C.
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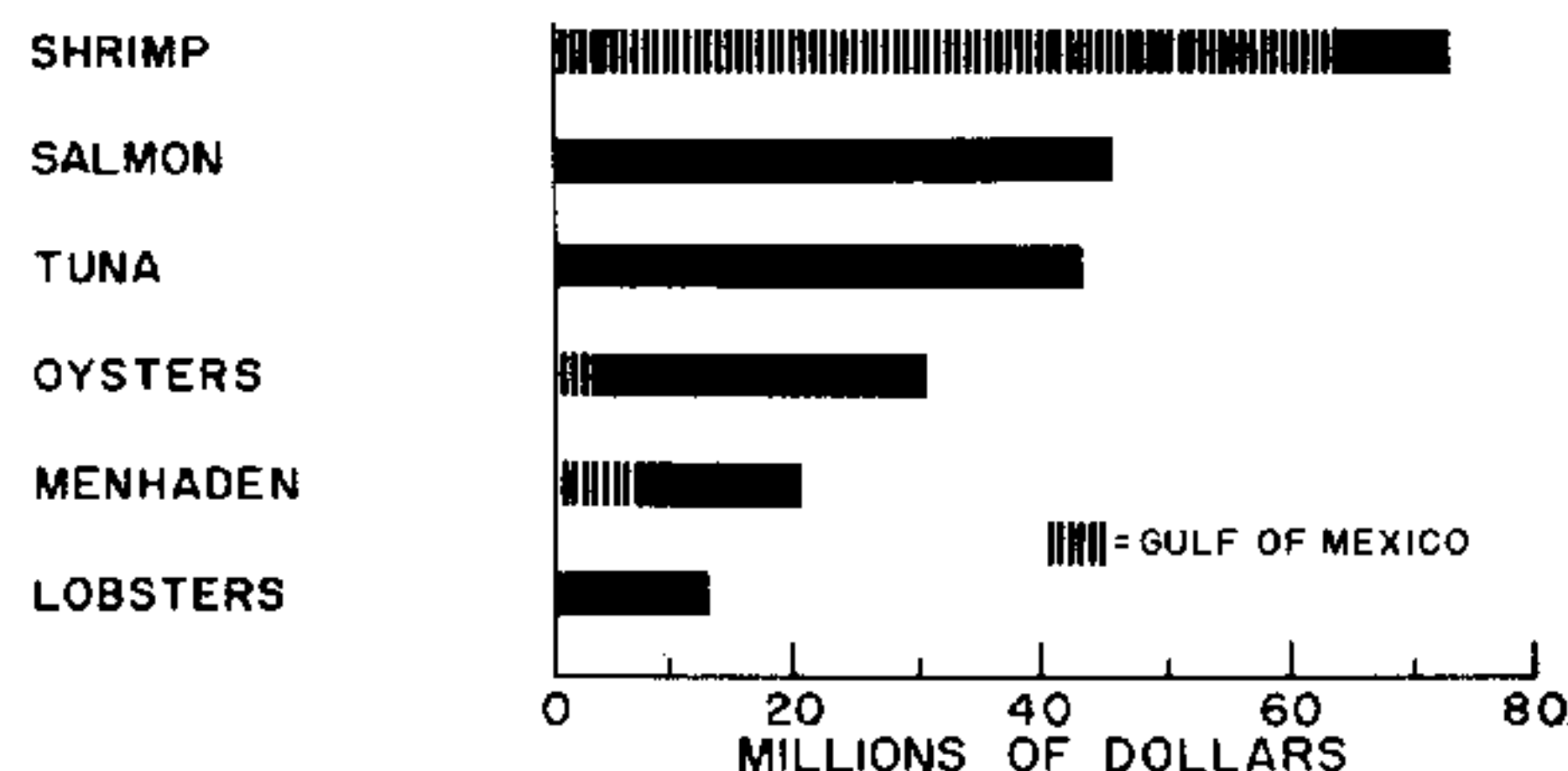
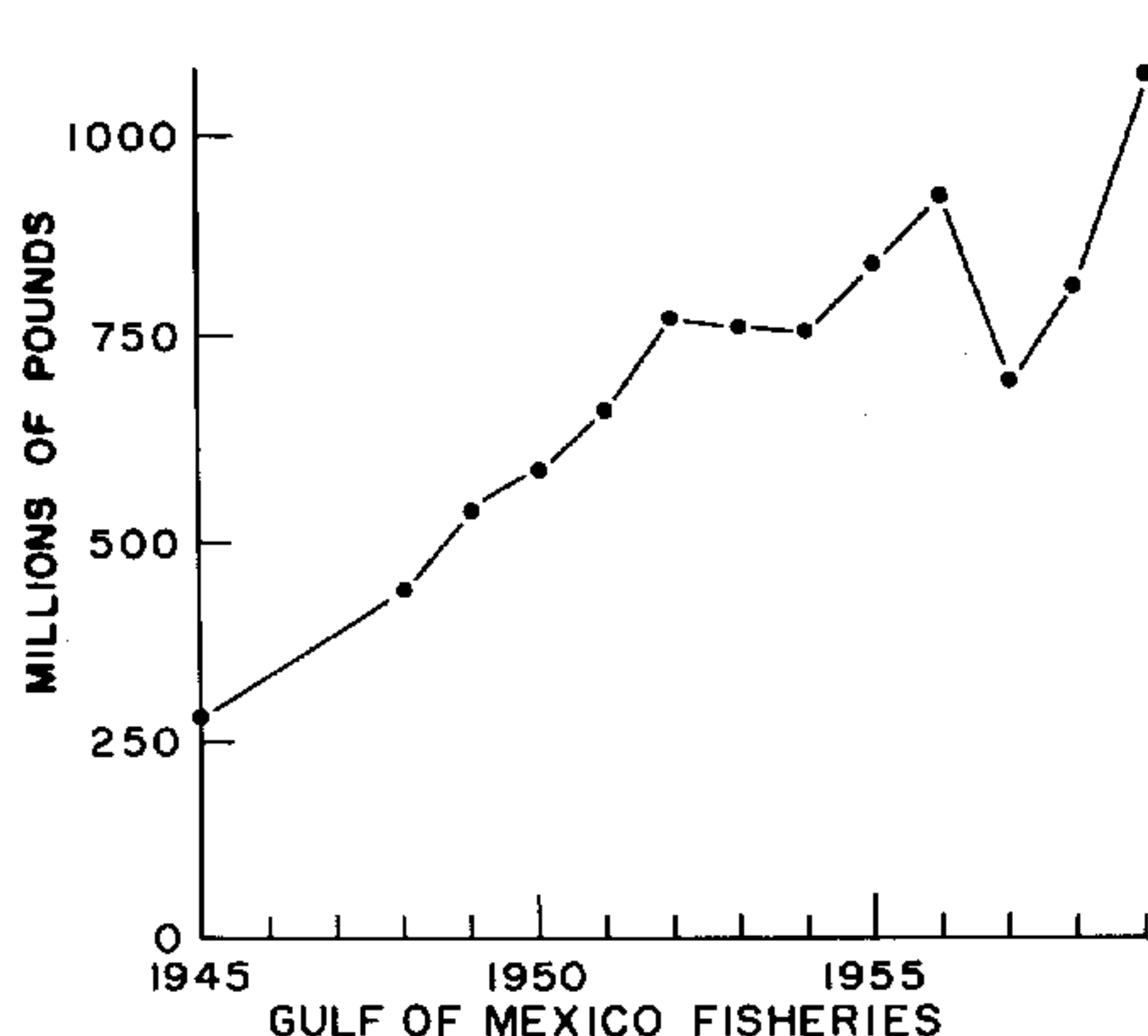
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REPORT OF THE DIRECTOR

George A. Rounsefell

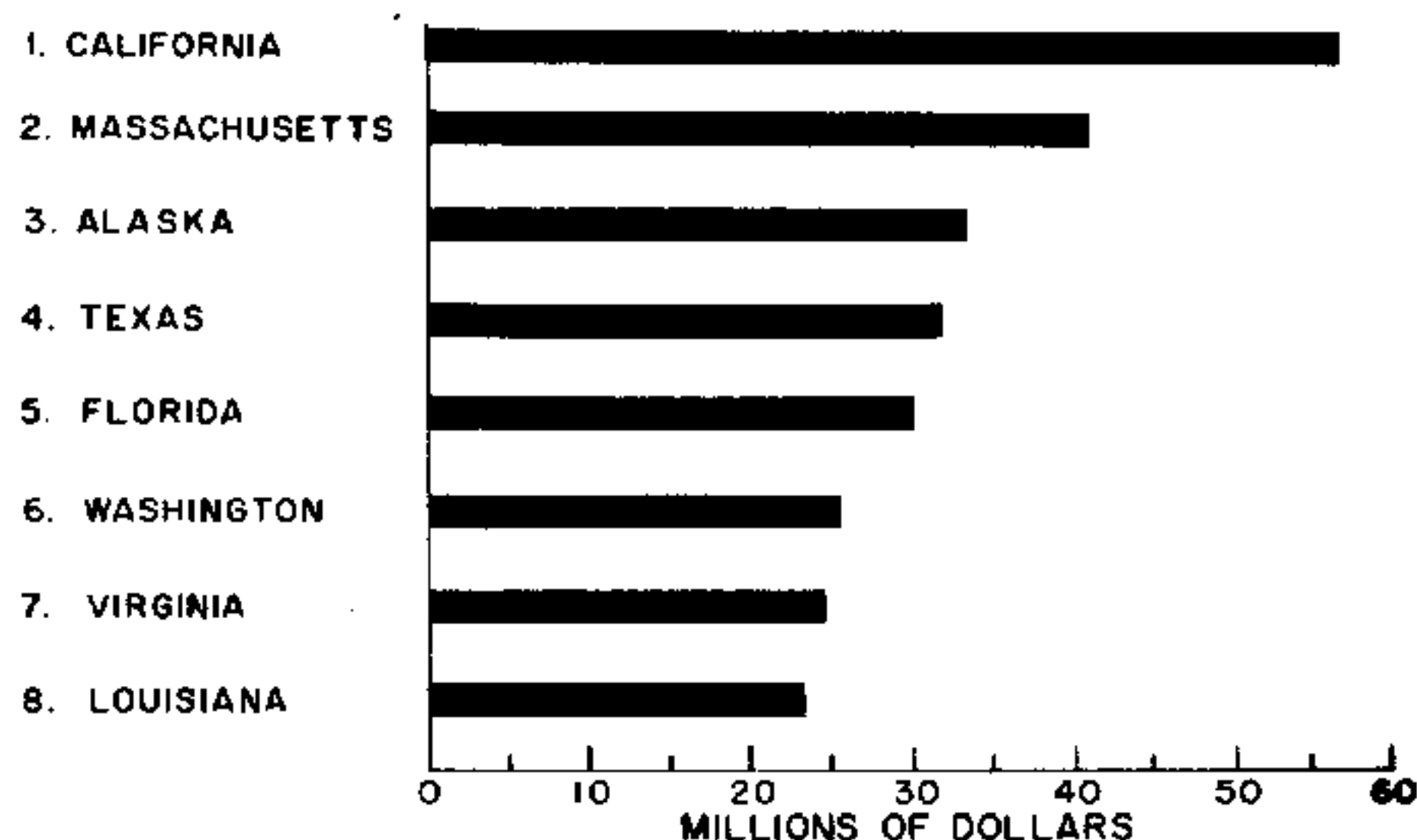
Expansion of Gulf of Mexico fisheries The Gulf of Mexico fisheries are still expanding steadily. In 1959 the total catch exceeded one billion pounds (1,137,000,000), which was greater than for the entire Pacific coast. The Gulf share of shrimp, the nation's most valuable species, was 64 million dollars out of a U. S. total of 73 million (raw catch at dockside). Three of the 5 Gulf states ranked among the first 8 of the 50 states in value of fishery landings during 1958. This rapid expansion offers a challenge; can we gain sufficient knowledge about the fishes and their responses to natural and man-induced changes to maintain and increase the yield from these rich waters?



Research highlights of the past year
Early larval stages of penaeid shrimp were identified and described for two species at the Galveston Laboratory and for another at the University of Miami under research contract.

These advances in specific identification are important toward estimation of the abundance, seasonal occurrence, and distribution of larvae of the several chief species of shrimp.

An initial allotment permitted us to start sorely needed work on the effects of insecticides on a broad spectrum of estuarine species. Tests of several of the chlorinated hydrocarbons show that shrimp, especially larvae and juveniles, are extremely sensitive to some insecticides. Thus, endrin was found to be toxic to juvenile brown shrimp at only 5 parts per billion! Lindane, dieldrin, heptachlor, and sevin were toxic to juveniles at



concentrations ranging from 8 to 27 parts per billion. Endrin is toxic to post-larval shrimp at only one-half of 1 part per billion and lindane, at 2 parts per billion!

Of great value to our red tide research is the systematic sampling of a limited area for numerous environmental factors, commenced in 1958. During the past year of heavy rainfall, large numbers of red tide organisms, and some fish mortality, we have for the first time secured detailed information concerning the complex hydrographic conditions preceding, accompanying, and following a red tide outbreak. In the laboratory we have developed a virtually inorganic culture medium to facilitate critical experiments on the nutrition of the red tide organism.

Over 4,000 compounds have been screened in an effort to find a practical poison for the red tide dinoflagellate. Several are much more toxic than copper sulphate, but all compounds must be tested for any effects on other marine fauna before contemplating field experiments.

Gulf States Marine Fisheries Commission The meetings of the Commission at Corpus Christi, Texas, and Mobile, Alabama, were attended. The meeting at Corpus Christi was preceded by a committee meeting at the Rockport Laboratory of the Texas Game and Fish Commission at which the programs for staining shrimp for migration studies were reviewed. The Commission later indorsed the Committee's recommendations concerning allocation of colored stains, minimum numbers to release, and payment of rewards. At the Mobile meeting Dr. Rounsefell reviewed recent advances in federal shrimp research and participated in the Shrimp Panel. The Estuarine Technical Coordinating Committee of the Commission composed of state and federal biologists is preparing maps showing fishery and other uses of the estuarine areas of the Gulf from Texas to Florida. The Committee is also maintaining a list of unpublished estuarine research data.

Southwest Field Committee of the Department of Interior The Seventy-First Meeting of the Committee was held at the Galveston Biological Laboratory in October. The members were given an account of the Bureau of Commercial Fisheries research activities, especially as related to the impact of water development plans of the U. S. Study Commission, and other agencies, on the estuarine environment.

U. S. Study Commission - Texas The purpose of the U. S. Study Commission - Texas is to approve water-use projects which best meet the state and national interests. Project plans of such agencies as the U. S. Bureau of Reclamation, U. S. Corps of Engineers, Texas Board of Water Engineers, and the Texas River Authorities will be studied and evaluated by the Commission. The Commission has created planning and advisory committees to study specific aspects of these plans. The U. S. Bureau of Commercial Fisheries is represented in the Fish and Wildlife Collaboration Group of the Commission.

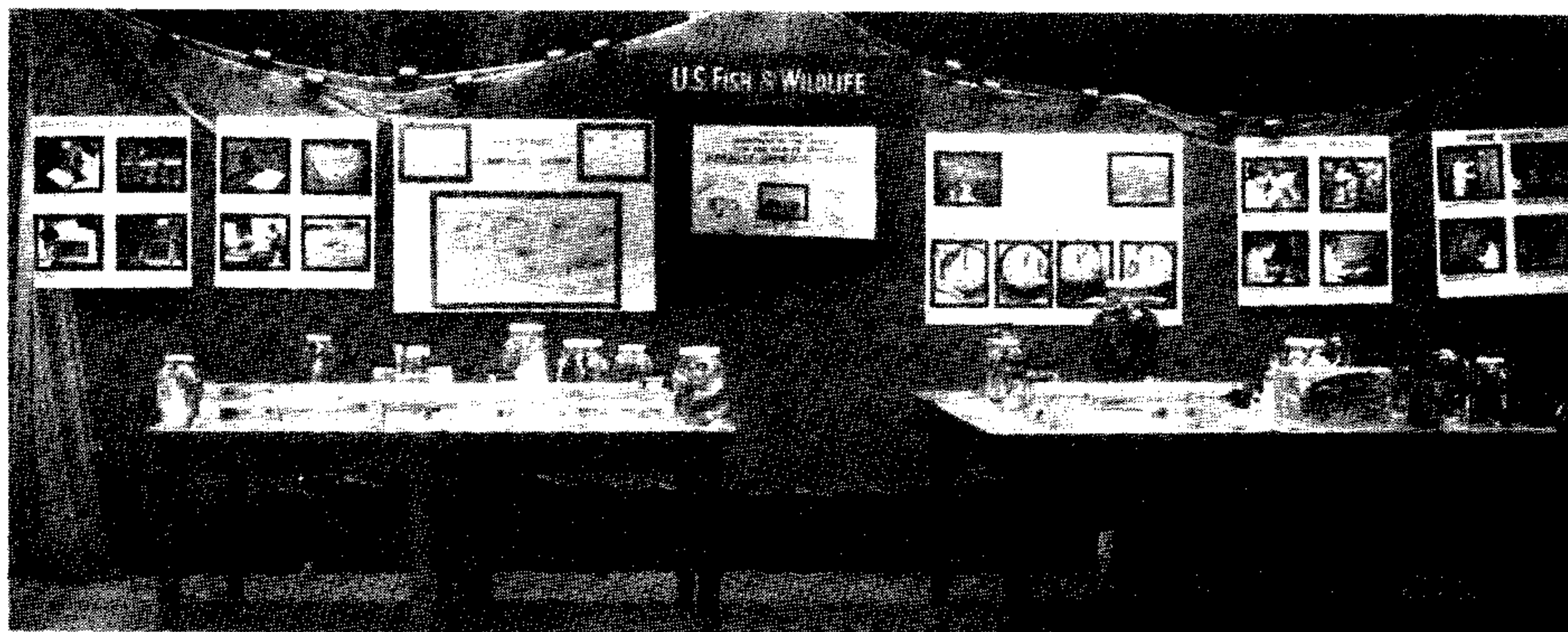
Other members of this committee include the U. S. Bureau of Sport Fisheries, Texas Game and Fish Commission, U. S. Bureau of Reclamation, U. S. Corps of Engineers, Texas Board of Water Engineers, U. S. Forest Service, and the U. S. Soil Conservation Service. There have been three meetings of this Collaboration Group to discuss the availability of fish and wildlife data pertinent to the Study Commission's activities. The Bureau of Commercial Fisheries has been requested to report to the Commission on the effects of the proposed water use projects on marine and estuarine organisms and their environments.

Work conferences During the year, conferences on various Gulf engineering projects were held with staffs of the U. S. Bureau of Sport Fisheries and Wildlife, the Louisiana Wildlife and Fisheries Department, the Texas Game and Fish Commission, and Texas A. and M. College. These included: (1) Mississippi River-Gulf Outlet Project with conferences in Galveston, Texas; and New Orleans and Hopedale, Louisiana, (2) Lake Pontchartrain Hurricane Studies in Galveston and New Orleans, and (3) Texas River Basin Studies in Galveston, Austin, and Rockport, Texas, and Albuquerque, New Mexico.

A conference on insecticide research in Galveston was attended by Dr. Victor Loosanoff of the Milford Biological Laboratory, Dr. Philip Butler of the Gulf Breeze Laboratory, and Dr. K. M. Rae and Mr. A. W. Collier of Texas A. and M. A priority listing was prepared of the insecticides to be studied.

Public Relations A staff member of the National Geographic Society spent 2 weeks at the Galveston Laboratory taking micrographs of red tide organisms and obtaining other technical data as a basis for a forthcoming article. Pure cultures of red tide organisms were sent to Dr. Bernard Abbott, University of California in Berkeley. Cultures of red marine bacterium toxic to fish were sent to the Torry Research Station of the Scottish Department of Scientific and Industrial Research.

The Laboratory's marine exhibit at the annual Galveston Home and Garden Show at Moody Center March 24-26 contained fish specimens, aquaria of live fish and marked shrimp, illustrations of phases of the work, and samples of collecting equipment.



STAFF

George A. Rounsefell, Director
Bernard E. Skud, Assistant Director

Biological Laboratory at Galveston, Texas
Field Stations at Miami, Florida
Pascagoula, Mississippi
St. Petersburg Beach, Florida

Red Tide Investigation

William B. Wilson	Chief	Galveston
David V. Aldrich	Biologist	Galveston
Billie Z. May	Head, Field Station	St. Petersburg
Alexander Dragovich	Biologist	St. Petersburg
John H. Finucane	Biologist	St. Petersburg
John A. Kelly, Jr.	Biologist	St. Petersburg
John D. McCormick	Master, M/V KINGFISH	St. Petersburg
McKinley W. Jambor	Biological Aid	St. Petersburg
Lucius Johnson, Jr.	Physical Science Aid	St. Petersburg
Alice Murphy	Biological Aid	Galveston
Domingo R. Martinez	Biological Aid	Galveston

Estuarine Ecology Investigation

Edward Chin	Chief	Galveston
Zoula P. Zein-Eldin	Biochemist	Galveston
Anthony Inglis	Biologist	Galveston
John G. VanDerwalker	Biologist	Galveston
Grant L. MacNichols	Biologist	Galveston
Gilbert Zamora, Jr.	Fishery Aid	Galveston
Genevieve B. Adams	Statistical Clerk	Galveston
Imogene A. Sanderson	Physical Science Aid	Galveston
William G. Wilkerson	Summer Aid	Galveston
Samuel C. Jernigan	Summer Aid	Galveston

Shrimp Fishery Investigation

Joseph H. Kutkuhn	Chief	Galveston
Thomas J. Costello	Head, Field Station	Miami
Abraham Fleminger	(Resigned 1/60)	Galveston
Donald M. Allen	Biologist	Miami
William C. Renfro	Biologist	Galveston
Ray S. Wheeler	Biologist	Galveston
Jack G. Robinson	Biologist	Galveston
Harry L. Cook	Biologist	Galveston
Kenneth N. Baxter	Fishery Aid	Galveston
James A. Eiland	Temporary Aid	Galveston
Hanford M. Harris	Temporary Aid	Galveston

Industrial Fishery Investigation

Edgar L. Arnold, Jr.	(Transferred 2/60)	Galveston
James P. Cating	(Transferred 2/60)	Galveston
Winthrop A. Haskell	Head, Field Station	Pascagoula
John M. Hutton, Jr.	Biologist	Pascagoula
Lawrence F. Schumacher, III	Summer Aid	Galveston

Staff Services

Chemistry Laboratory

Kenneth T. Marvin	Chief Chemist	Galveston
Larence M. Lansford	Chemistry Aid	Galveston
Raphael R. Proctor, Jr.	Fishery Aid	Galveston

Effects of Engineering Projects

Ronald C. Naab	Biologist	Galveston
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Library

Stella Breedlove	Librarian	Galveston
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Technical Services

Ruth W. Yanch	Secretary	Galveston
Esther E. Sell	Secretary	Galveston
Daniel Patlan	Draftsman	Galveston
Petronila C. Prado	Scientific Stenographer	Galveston
Mary E. Hipple	Clerk-typist	St. Petersburg

Administration and Maintenance

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Laura M. Hermann	Asst. Admin. Officer	Galveston
Corinna L. Denbo	Purchasing Clerk	Galveston
Glo S. Baxter	Clerk-Stenographer	Galveston
Peter M. Villarreal	Maintenanceman	Galveston
Robert L. McMahon	Maintenanceman	Galveston
Tidas C. Alcorn	Maintenanceman	Galveston

SHRIMP FISHERY INVESTIGATION

Joseph H. Kutkuhn, Chief

Three areas of study concerned with measuring some portion of the shrimp resource, commanded attention during the year. These were: (1) larvae and post-larvae; (2) juveniles; and (3) adults. An understanding of the dynamics of each population phase constitutes the basis for establishing sound resource management. Such programs embrace the goals of (1) predicting yield and, correspondingly, (2) apportioning exploitation so that, under prevailing and anticipated environmental conditions, commercial shrimp populations will sustain themselves at maximum production levels.

A major impediment in studying larvae and post-larvae has been an inability to distinguish between species. Significant advances in specific identification of penaeid larvae can be reported for the past year. Early larvae derived from known parents have been described for two species at this laboratory, and for another at the University of Miami, the latter work having been done under contract. At this writing, prospects of obtaining comparable results with several other species appear very good.

Studies of abundance and distribution of penaeid shrimp larvae in the Galveston area proceeded as outlined in our 1959 report. A year's intensive systematic plankton sampling ended in March. Awaiting specific identification are penaeid and other shrimp larvae whose sorting is well ahead of schedule.

Juvenile commercial shrimp occur in estuarine environments where they are exploited for sale as sport fishing bait. A survey of bait shrimping in Galveston Bay is providing information on (1) the numbers caught, and (2) their numbers relative to those before and after occupying the so-called nursery area. An estimate of early natural mortality appears possible.

By marking and releasing juvenile shrimp on known nursery areas, and noting where they are later recaptured, boundaries of the nursery areas for the pink shrimp supporting the important Sanibel-Tortugas (Florida) fishery are gradually being set. This technique offers promise of circumscribing habitats and hence populations of commercial shrimp in other Gulf areas.

Other studies are concerned with (1) shrimp growth, with the aim of eventually being able to sort commercial and research vessel catches into their component broods or age classes through indirect aging, this, in turn, permitting estimation of adult-population mortality rates; and (2) routine analyses of commercial shrimping statistics as applicable in studies of population dynamics and industry economy.

Experiments in Rearing Shrimp Larvae

Ray S. Wheeler

The young of many decapod species commonly occurring together in Gulf waters are noticeably alike in size and structure. Understandably, this fact greatly complicates studies of the dynamics of individual species' populations. Considerable effort is being made to differentiate commercial and related varieties at corresponding developmental stages. Three methods of securing necessary material have been tried. Briefly, these are:

1. Rearing penaeid larvae of known parentage under laboratory conditions from eggs naturally fertilized and spawned, a record being maintained of all morphological changes occurring between molts.
2. Rearing penaeids of known parentage under laboratory conditions from eggs taken from gravid females and artificially fertilized with spermatozoa obtained from mature males, a record of subsequent morphological changes being maintained.
3. Rearing unidentified penaeid-like larvae collected in plankton nets to an identifiable stage, a record of all morphological changes being kept as described above.

Mature specimens of nine penaeids, Penaeus aztecus, P. duorarum, P. setiferus, Sicyonia spp. (2), Xiphopeneus krøyeri, Trachypeneus similis, T. constrictus, and Solenocera atlantidis; two carids, representatives of the Families Hippolytidae and Pandalidae; and one stomatopod, Squilla sp., have been intermittently maintained in the laboratory with special attention centering upon P. aztecus. Information supplied by local commercial shrimpers and Bureau of Commercial Fisheries statistical agents was helpful in determining when and where gravid females of all species could be most easily obtained. These were collected with conventional shrimp trawls fished for short periods to prevent injury from compaction. Ripe adults were brought promptly to the laboratory, the water in their containers being frequently changed en route.

Pairs, trios, and groups of four or more shrimp were kept in separate aquaria supplied with continuously filtered sea water of about 30‰ salinity. Water temperatures maintained in different aquaria ranged from 20° to 30° C. Diet and light intensity were also varied in attempts to induce maturation and spawning. Daily samples of bottom deposits from each aquarium were examined microscopically for eggs. Laboratory observations over a 1-year period revealed that:

1. Gravid females in an advanced stage of maturity usually spawned or aborted within 48 hours after being brought into the laboratory.

2. The ovaries of gravid females not fully mature gradually regressed and never again attained spawning condition despite all attempts to induce it. (Specimens of several species were maintained in the laboratory for periods ranging from a few months to almost a year.)

3. Hormones (e.g., pregnenolone, testosterone propionate, and pituitary powder) injected into individual specimens, mixed with their food, or dissolved in aquaria water had no apparent effect on adult shrimp of either sex.

4. Molts occurred at regular intervals--usually at night.

5. Mating, which involves transfer of spermatophore from male to female, takes place in the confines of laboratory aquaria.

Eggs were obtained from incipient spawners of all species brought to the laboratory. In each instance an around-the-clock schedule was maintained to care for spawn and any larvae hatched therefrom. Larvae of P. aztecus and Xiphopeneus krøyeri were reared through a varying number of naupliar instars to Protozoa I. Larvae from eggs of P. duorarum were carried to Nauplius I. Eggs of all other species failed to hatch, probably because of infertility.

The primary difficulty experienced in rearing larvae to any stage was an inability to control predaceous microorganisms, mainly ciliates, despite the use of filtered water in holding aquaria and the frequent changing of sterile-water rearing media. Experiments in which various chemicals were tested for their capacity to control microorganisms have thus far been unsuccessful. Concentrations sufficient to check microzoan populations proved lethal to shrimp larvae.

Attempts to fertilize P. aztecus and P. setiferus eggs artificially are not yet successful.

Post-larvae of P. aztecus, 10 mm. long when collected and reared through successive molts, attained a length of 38 mm. within 6 weeks. Best growth was obtained by feeding maximal amounts of brine shrimp (Artemia sp.) larvae; poorest growth with a pure algal (Skeletonema sp.) diet.

Though several species have been reared successfully from eggs to Protozoa I and, in one species, from an early post-larval to juvenile stage, material representing intermediate instars (Protozoa II--early post-larvae) is still lacking. However, in view of steady progress being made in improving rearing techniques, it appears to be a matter of time before gaps in our knowledge of the development of each species will be closed.

Abundance and Distribution of Penaeid Shrimp Larvae

William C. Renfro

Any program concerned with gaining a better understanding of population dynamics needs knowledge of the size of new broods as they are produced periodically. Study of shrimp population characteristics involves critical appraisal of stock-progeny relationships and estimation of natural mortality during early developmental stages.

A study was implemented in early 1959 to explore the possibility of assessing brood sizes and describing distributional patterns during larval and post-larval stages. Its initial phase, systematic plankton sampling in waters adjacent to Galveston Island, was completed in March. Samples were taken with appropriate gear from each of three depths (5 feet, 20-30 feet, and bottom): (1) once weekly at 16 stations located on transects radiating seaward from Galveston Entrance, and (2) at least twice weekly from 8 stations maintained in Galveston Entrance and Bolivar Roads. A few samples were also taken in San Luis Pass at the western end of Galveston Island.

During the 53 weeks between the first sampling cruise on March 17, 1959, and the last cruise on March 21, 1960, offshore stations were occupied 41 times and inshore stations 115 times. A total of 3,163 plankton samples was collected, 1,508 from offshore stations and 1,614 from Bolivar Roads-Galveston Entrance. Seven cruises to San Luis Pass yielded 41 samples from that area. Because of time and cost, sampling at this location was discontinued in August 1959. Processing of samples consists of microscopically examining the contents of each sample (or known fractions thereof) and sorting out all penaeid-like forms. Specific identification of these will follow as soon as methods for doing so are devised.

To date 18 percent of the plankton samples have been examined. Although most penaeid-like larvae cannot be specifically identified or their stage of development designated, some general statements based on material sorted thus far can be made. Twenty Nauplius II taken at a depth of 20-30 feet, 15 nautical miles offshore on May 8, 1959, represented the earliest larval stage noted at any regular collecting station. The earliest larval stage found in Galveston Entrance was represented by 25 Nauplius IV taken during June from a depth of 5 feet just off the Galveston Jetties. Post-larvae as long as 8 mm. were occasionally taken at those stations farthest offshore but were most abundant at inshore stations. Mysis I and II were frequently taken at the latter stations.

The table provides a crude indication of the relative abundance of penaeid-like larvae at two depths. It must be emphasized that these are preliminary data obtained from notes made during sorting operations. No correction has been made for volumes of water sampled, and designation of developmental stages is tentative. Regarded as minimal, the figures represent unadjusted counts of penaeid-like larvae collected at offshore stations from depths

of 5 and 20-30 feet during seven cruises made between March 24 and July 15, 1959. Speaking provisionally, they suggest that more larval stages were present at mid-depths. And, although comparable data are not yet available, results of collections made on the bottom indicate that representation of all penaeid larval stages is, on the average, even better there. Discounting possible phototropic responses, all early larvae appear to be predisposed to transport in the lower depth strata.

Bathymetric distribution* of penaeid-like larvae sorted from
plankton samples obtained during seven cruises off Galveston:
March-July 1959

Developmental stage	Depth of collection	
	Surface (5 feet)	Mid-depth (20-30 feet)
Nauplius I-III	0	50
Nauplius IV-V	150	100
Protozoaea I-III	6, 100	12, 400
Mysis I	2, 350	5, 300
Mysis II	900	1, 000
Post-larvae	250	1, 000
All stages	9, 700	19, 850

* Bottom samples not yet sorted.

To provide data complementary to those secured through sampling the deeper waters adjacent to Galveston Island, a routine survey of conditions in corresponding shore-zone areas was initiated during the year. Collecting gear consists of a small-mesh nylon "beam" trawl with a 1-foot, #1-mesh plankton net fitted to its cod end. Started in November 1959, this survey entails sampling the plankton twice weekly at a single station located on the sand flats just inside the south Galveston Jetty. It will permit monitoring late- and post-larval stages of penaeid shrimps as they pass through Galveston Entrance to inshore nursery grounds.

The first penaeid post-larvae appeared in a sample taken January 8. They were taken in small numbers until the 2nd week in March when they began to appear in greater numbers; peak abundance occurred from mid-March to mid-April. Post-larvae collected during the latter part of March and reared to an identifiable size in the laboratory proved to be brown shrimp, Penaeus aztecus. These observations corroborate the sequence of events in this species' life history outlined by other workers.

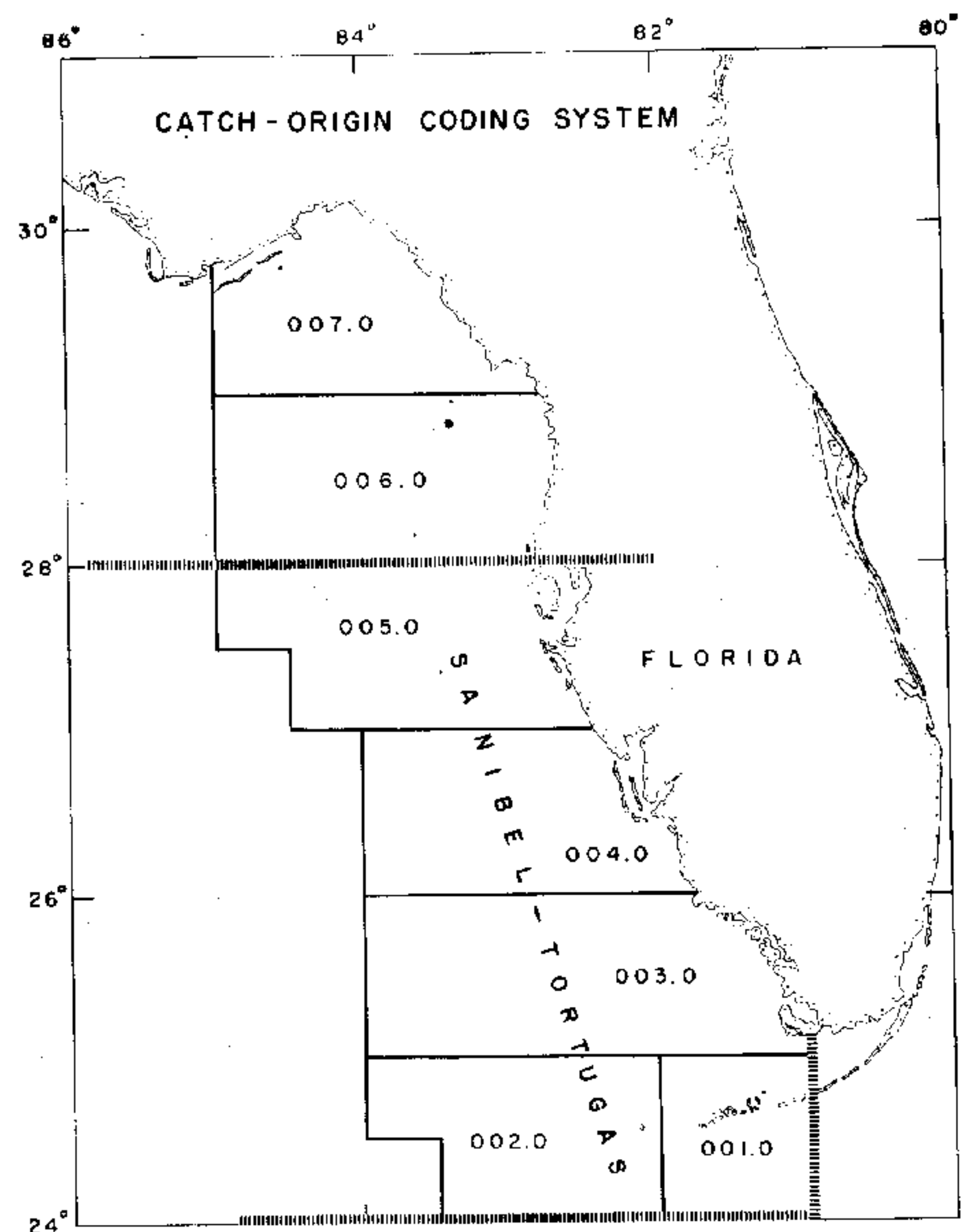
The Sanibel-Tortugas Shrimp Fishery: 1956-1959

Joseph H. Kutkuhn

In 1956 the Bureau of Commercial Fisheries initiated a comprehensive collection system of shrimp statistics in the Gulf of Mexico. A considerable mass of data on commercial shrimping and catch has since accumulated. Gross analyses of these statistics now permit us to document (1) the basic structure of exploitable portions of defined shrimp populations, and (2) the nature, efficiency, and effects of shrimping practices. The following discussion briefly summarizes what is revealed by statistics of commercial operations involving a single species inhabiting a small portion of the Gulf's extensive shrimping grounds.

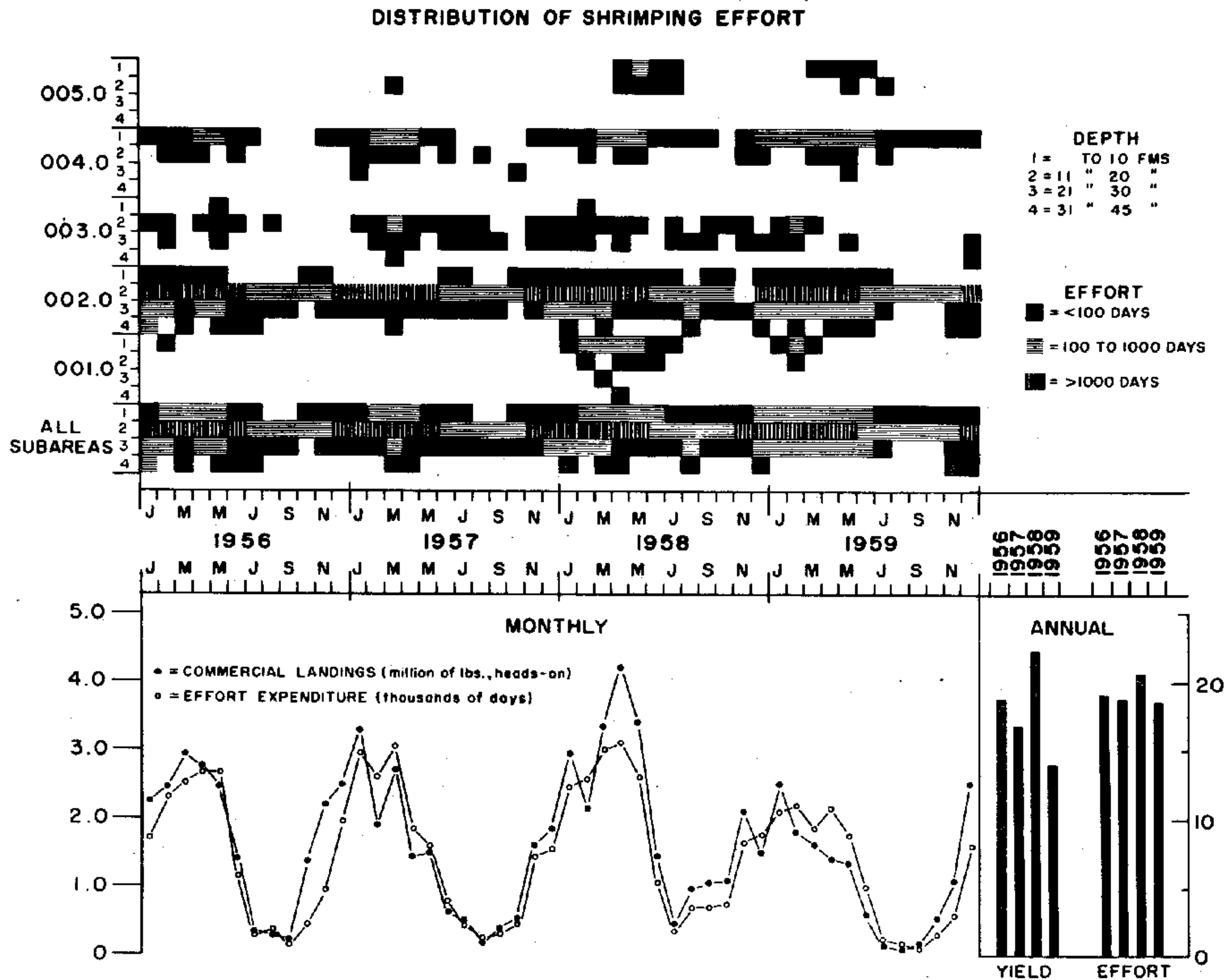
Description of the fishery First undergoing intensive exploitation about a decade ago, the pink shrimp (*Penaeus duorarum*) population occurring off southwest Florida has since supported a valuable commercial fishery. Arbitrarily delineated, its habitat extends coastwise from the vicinity of Tarpon Springs on the north to just beyond the Keys on the south. The seaward limit at all points has been set at the 45-fathom contour. Within these boundaries, the population disperses itself over a projected bottom area of some 23,000 square nautical miles. Adult and subadult shrimp are harvested throughout the year by trawling in the deeper offshore waters, some juveniles are taken seasonally in shallow inshore waters for sport fishing bait.

Shrimp taken commercially for table use are principally landed and processed at Tampa, Fort Myers, and Key West. Though some are sold fresh locally, most are frozen for later consumption by local and national markets. A recent and significant development in the Sanibel-Tortugas fishery has been the increased exploitation of shrimp too small for fresh and frozen outlets but ideally suited for canning. These are taken mainly by vessels operating out of, and shipped by various means to canneries located at, upper Gulf coast ports.



Biostatistical areas used in collection of shrimp statistics.

Nature of exploitation Commercial shrimping on the Sanibel-Tortugas grounds continues with varying intensity the year round (see figure). Spatial distribution of trawling effort follows a somewhat regular pattern. Greatest concentrations occur between 5 and 25 fathoms just north of the Dry Tortugas (subarea 002.0) and in 5 to 15 fathoms off Sanibel Island (subarea 004.0). Of interest in recent years has been the gradual extension of shrimping operations to intermediate and outlying areas though untrawlable bottom precludes more intensive shrimping on many of these.



Analysis of fishing effort for pink shrimp in Sanibel-Tortugas area, 1956-59.

In general, landings have maintained a close relation with the trawling effort expended. But, while seasonal and annual fluctuations in yield are to be expected, a steadily declining trend in annual yield over the past 4 years despite a static expenditure of effort gives rise to some concern. Clues to the cause(s) of this decline must first be sought in the exploited stock whose characteristics may be revealed through close scrutiny of yield structure.

Measurement of fishable biomass If fishing is random with respect to the size composition of the fishable stock, then the average rate of harvest (in pounds) may be considered proportional to the size of the fishable stock at time of harvest. By combining catches-per-unit-of-effort for each shrimping ground subarea, monthly indices to the population's overall fishable biomass^{1/} can be derived. This is accomplished through a process of two-way stratification (coastal zone x depth zone) wherein each subarea's yield/effort ratio is weighted by a factor denoting relative subarea size. In effect, the method eliminates, from the resulting index, biases due to uneven distribution of effort on the trawling grounds. Indices so derived are equivalent to the ratio of the yield to the effective overall fishing intensity except that effort data employed here have not been standardized. For the present, therefore, we must assume that errors attributable to differential efficiency of trawlers and gear were random. One further assumption made is that any portion of the population otherwise vulnerable but unavailable because of untrawlable bottom, represents a constant fraction of the total fishable stock.

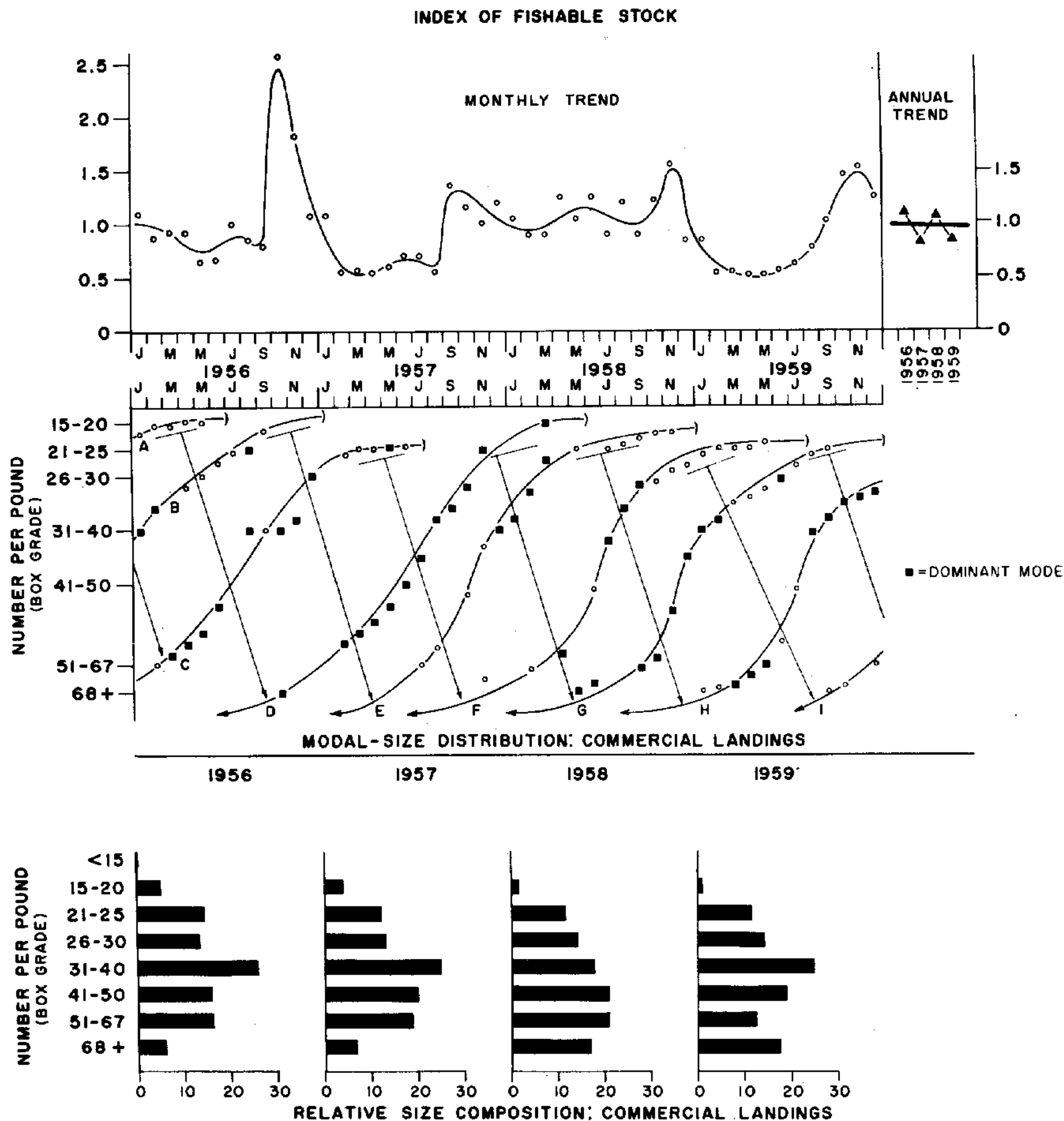
Monthly indices for the Sanibel-Tortugas pink shrimp population reveal that during the 4 years with available data the fishable biomass maintained itself within fairly narrow limits (see figure next page). Seasonal deviations of large magnitude are, of course, evident and to be expected. But reduced population levels sustained through the early months of 1957 and 1959, and the perceptibly downward population trend over the 4-year period, are the items of prime concern here.

A comparison of the fishable stock with the yield curve (see figures) indicates with one notable exception little correspondence between yield and stock size. This suggests that for most of the period 1956-59, shrimping practices were consistent with adequate stock maintenance. The exception noted occurred during the first two-thirds of 1959 when low yield paralleled low fishable stock. Since any feature of the dynamics of the resource is serially correlated with preceding events, an explanation would entail examining prior stock structure in relation to the mechanics of exploitation.

Biomass structure as determined from catch The shrimp industry's tradition of demanding higher prices for larger shrimp provides an incentive for fishermen and processors to sort landings into size classes. Yield statistics accordingly afford a crude picture of population age structure and growth. Relative strengths and the succession of broods in the fishable biomass can be shown graphically by simply plotting modal sizes reflected in the size breakdown of each month's landings (see figure next page).

^{1/} If yields were reported in terms of numbers of shrimp, a comparable index would be stated in terms of "density" or abundance."

Again assuming shrimping is mainly non-selective we note for the Sanibel-Tortugas pink shrimp population that (1) on the average, two broods are recruited each calendar year; (2) at times, three broods can be expected to



Analysis of pink shrimp statistics for Sanibel-Tortugas area, 1956-59.

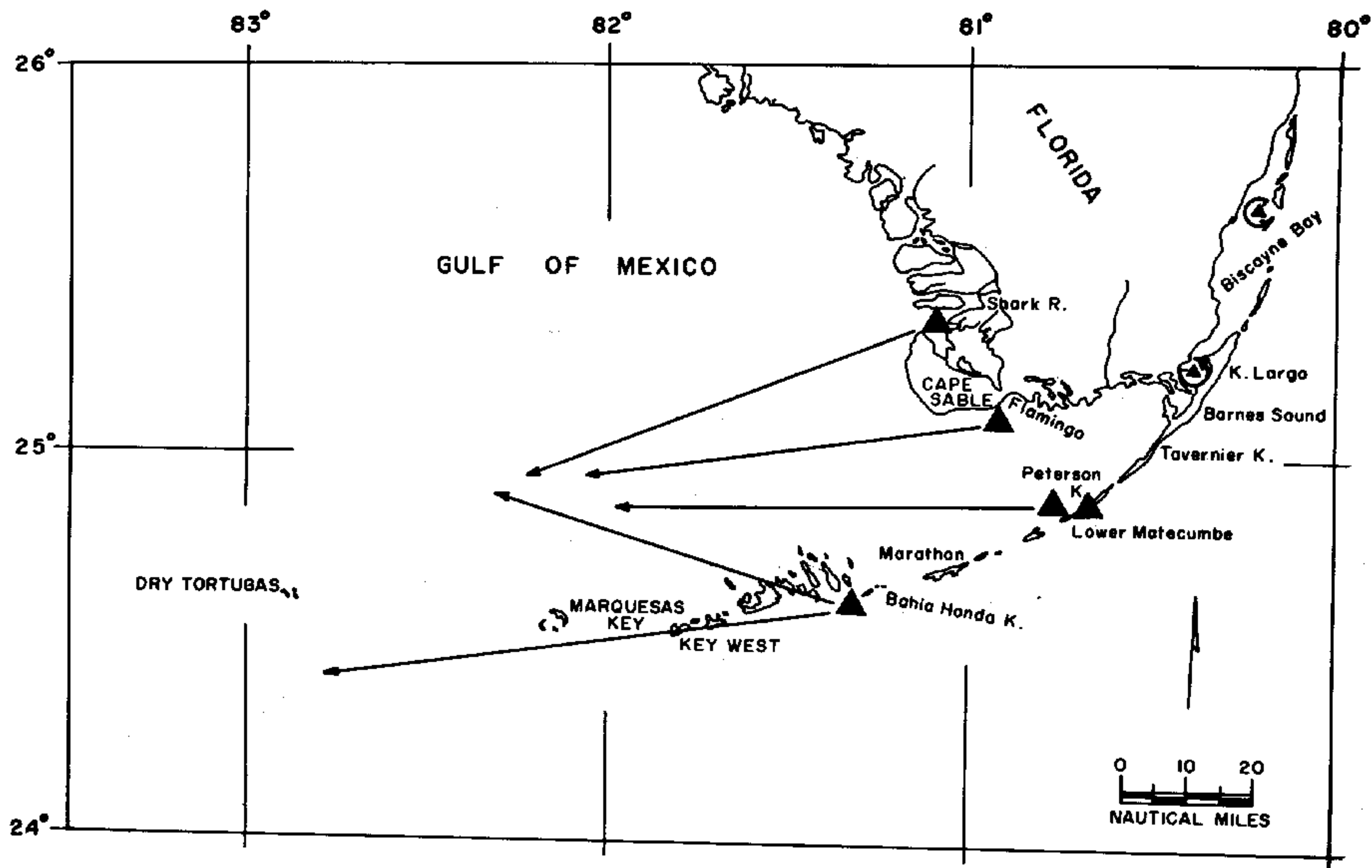
contribute to any month's landings; (3) growth is quite uniform from brood to brood; (4) some broods are definitely stronger than others and contribute significantly to the fishery throughout their existence; and (5) a direct relationship between size of spawning stock and resulting brood is mildly suggested.

Analysis of yield trends To explain the decline in population and corresponding yield for 1959, one needs to examine the histories of those broods that supported the fishery for that year. Comparing figures we see that the greatest proportion of each annual harvest is taken early in the calendar year; yields at this time are usually of larger shrimp--the remnants of dissipating broods; and the fishable stock is presumably at its normal level. But, retracing the histories of the two broods sustaining 1959's fishery (curves F and G), it is seen that, although yields during the early months comprised larger shrimp, their mass was greatly reduced, this condition apparently resulting from excessive fishing in mid-1958. The inference here is reasonably clear; both broods, particularly the latter, suffered disproportionate exploitation while they were small. A similar condition is indicated for 1956-57 except that the harvest of small shrimp in 1956 was measurably less than that in 1958.

Migration of Pink Shrimp

Thomas J. Costello and Donald M. Allen

Delineation of Tortugas nursery areas Mark-recovery experiments circumscribing the pink shrimp (*Penaeus duorarum*) population fished commercially off southwest Florida continued during the year. Three experiments complemented those conducted in 1958 and 1959, all of which demonstrate that some (and probably most) portions of Florida Bay serve as "nursery" areas for broods contributing to the Tortugas fishery.

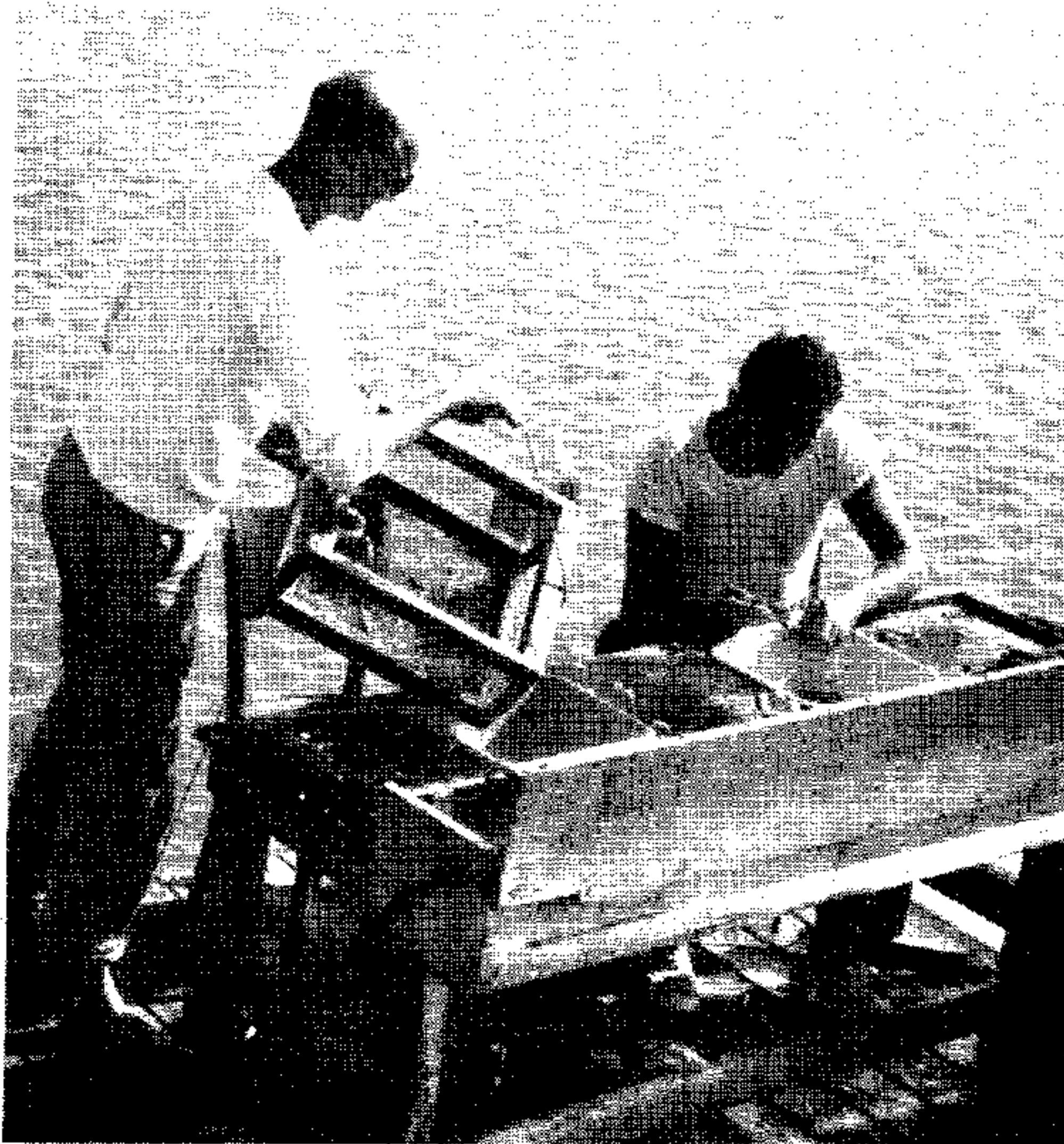


Migration of juvenile pink shrimp from South Florida inshore waters as mark-capture experiments. Arrows show the possible routes to recapture areas.

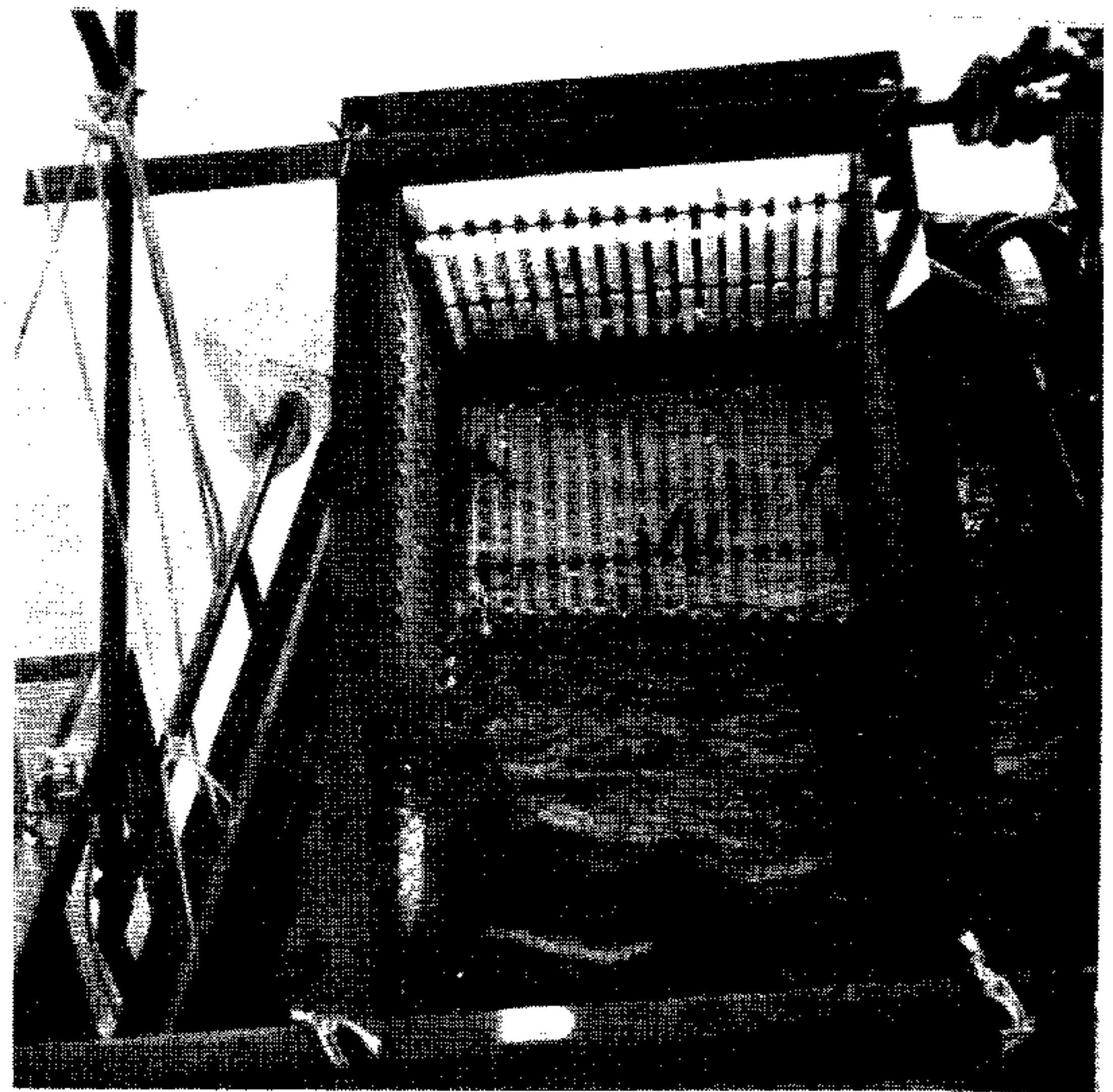
The figure shows release and recovery sites for experiments conducted through May 1960. All recoveries from the Flamingo, Peterson Key, and Shark River experiments were made just north of Dry Tortugas and definitely reflected concentration of shrimping effort there. They nevertheless corroborate the premise that Florida Bay estuaries provide habitat essential to the development of newly produced broods which ultimately sustain the valuable Sanibel-Tortugas fishery.

Small numbers of pink shrimp, stained and released as juveniles in the Atlantic Ocean southwest of Bahia Honda Key, have also been recaptured north of Dry Tortugas, indicating that some shrimp nurtured in east Florida Bay migrate through the lower Keys and support the seasonal Hawk Channel fishery.

All recoveries of marked shrimp released in Biscayne Bay and Barnes Sound were made in the immediate vicinity of release. The Barnes Sound experiment is particularly interesting since marked shrimp were still being recovered there more than $5\frac{1}{2}$ months after release, suggesting they represented a sedentary population.



Staining shrimp at Bahia Honda
for migration studies.

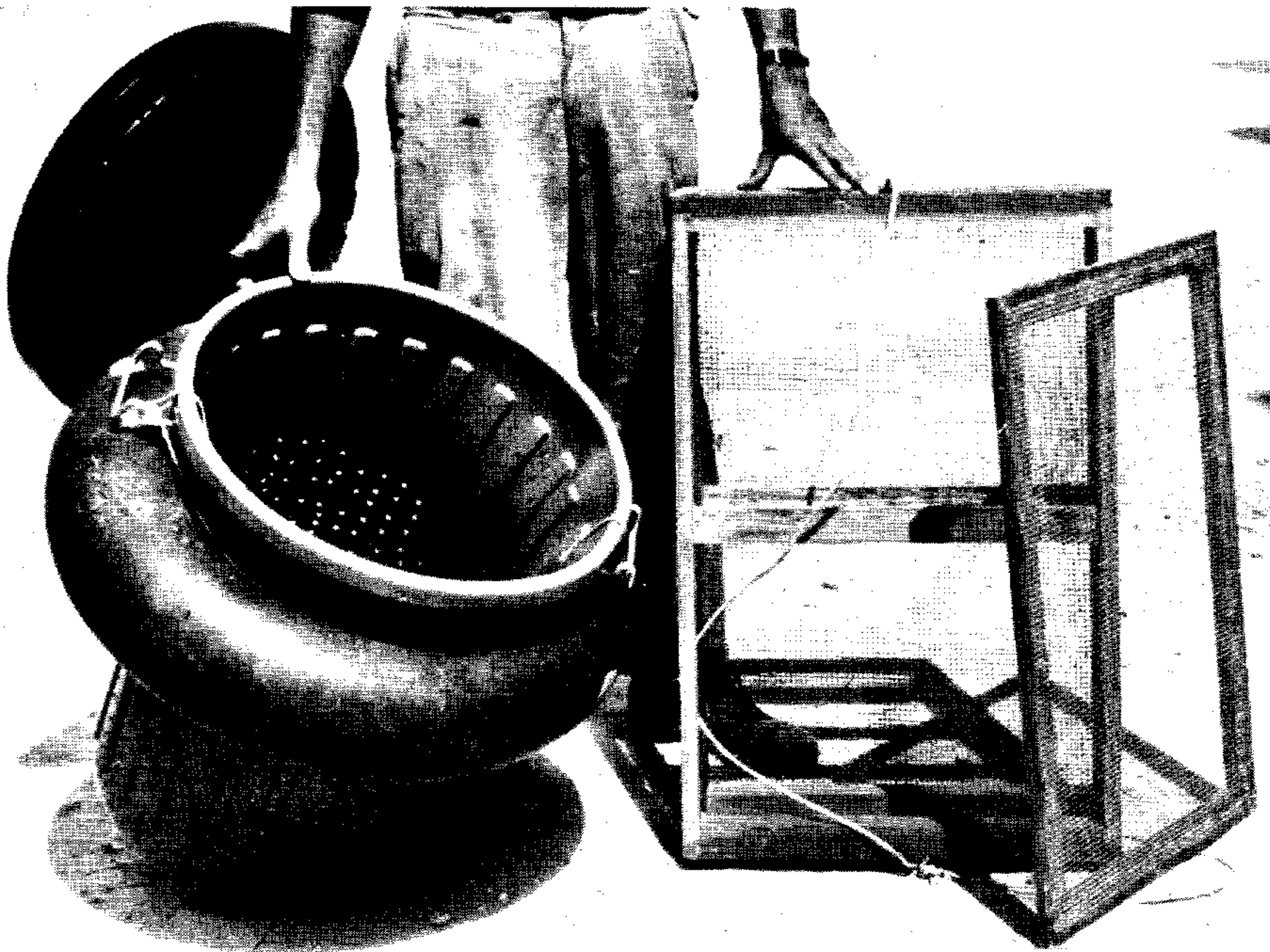


Grader of plexiglas rods for sorting
shrimp into size groups prior to
staining and releasing.

Stained pink shrimp release-recovery information:
Florida Bay and adjacent waters, 1958-1960

Release area	Date released	No. released	No. recovered ^{1/}	Recovery period	Recovery area
<u>1958</u>					
Biscayne Bay	Apr.-May	19,358	57	May-July 1958	Biscayne Bay
Flamingo	October	7,264	4	Jan.-Feb. 1959	N. of Dry Tortugas
<u>1959</u>					
Peterson Key	January	1,729	11	Mar.-May 1959	N. of Dry Tortugas
Matecumbe Key	March	1,672	0		
Barnes Sound	July	7,084	29	Aug. 1959-Jan. 1960	Barnes Sound
Shark River	Nov.	16,638	31	Dec. 1959-Mar. 1960	N. of Dry Tortugas
<u>1960</u>					
Bahia Honda Key	Feb.	6,815	17	Mar.-May 1960	N. of Dry Tortugas

^{1/} Verified marks recovered by June 1960



Two types of floating containers to hold stained shrimp prior to their release.

Tags versus dyes for shrimp-marking Anticipating the use of stains or tags to estimate mortality rates in shrimp populations, two experiments comparing survival of stained and tagged shrimp were conducted in a pair of large concrete tanks. Each tank (18 by 6 by 2 feet) was provided with screened sea water circulating at the rate of 4 gallons per minute from a common source. Locking covers precluded entry of debris. Salinity and temperature remained constant in both tanks throughout both experiments.

Three hundred male and 300 female pink shrimp ranging in carapace length from 20 to 24 mm. were selected for the first experiment. Into each tank were placed 300 specimens, 50 of each sex tagged with Petersen discs, 50 injected with dye, and 50 unmarked. One tank then received predators represented by four mangrove snappers, Lutjanus griseus, while the other remained as a "control."

The second experiment differed from the first in that (1) only females of a size slightly larger than before were used and (2) no predators were placed in either tank.

Differential survival for 10 days of tagged, stained, and unmarked pink shrimp

Treatment	Number per tank	Survivors			
		Experiment I		Experiment II	
		Tank 1	Tank 2 ^{1/}	Tank 1	Tank 2
Tagged	100	68	12	68	66
Stained	100	84	49	94	93
Controls	100	88	40	86	87

^{1/} Tank also contained four mangrove snappers, Lutjanus griseus

Inspection of the table reveals that stained and unmarked shrimp survived at essentially the same rate. Tagged shrimp suffered disproportionately higher mortality in the first experiment due to the combined effects of tagging itself, and predation. Unfortunately, an evaluation of each factor is impossible because replicate data are lacking. The second experiment's results do suggest, however, that predation by the fish was responsible for the highest mortality.

INDUSTRIAL FISHERY INVESTIGATION

Bernard E. Skud, Acting Chief

More than half of the United States' commercial fishery landings in 1959 were for industrial utilization -- oil, meal, and petfood. The Gulf contribution to these landings exceeded 800 million pounds, over 200 million pounds more than were taken in any previous year. The continued growth of this industry, which operates mainly in the north-central region, is indicative of the enormous potential of fishery resources in the Gulf.

Contract research on menhaden with the Gulf Coast Research Laboratory at Ocean Springs, Mississippi will continue until early 1961. The objectives of this research are to define discrete populations of menhaden, to determine the distribution and location of spawning grounds, and to describe menhaden life history.

Research on the demersal species was initiated during the fall of 1958 and has provided an assessment of the extent and value of this fishery. This is one of the few instances in which biological and statistical data have been gathered since the inception of a fishery and such a background should prove invaluable as expansion continues.

Clupeoid fishes, other than menhaden, are one of the promising sources of still another industrial fishery. In cooperation with the Bureau's Branch of Exploratory Fishing, our Investigation is sampling catches taken on exploratory cruises. Samples are available from 1958 and are Gulf-wide in distribution. Preliminary data collected from these samples include species identification, length-weight, sex, stage of maturity, and seasonal occurrence.



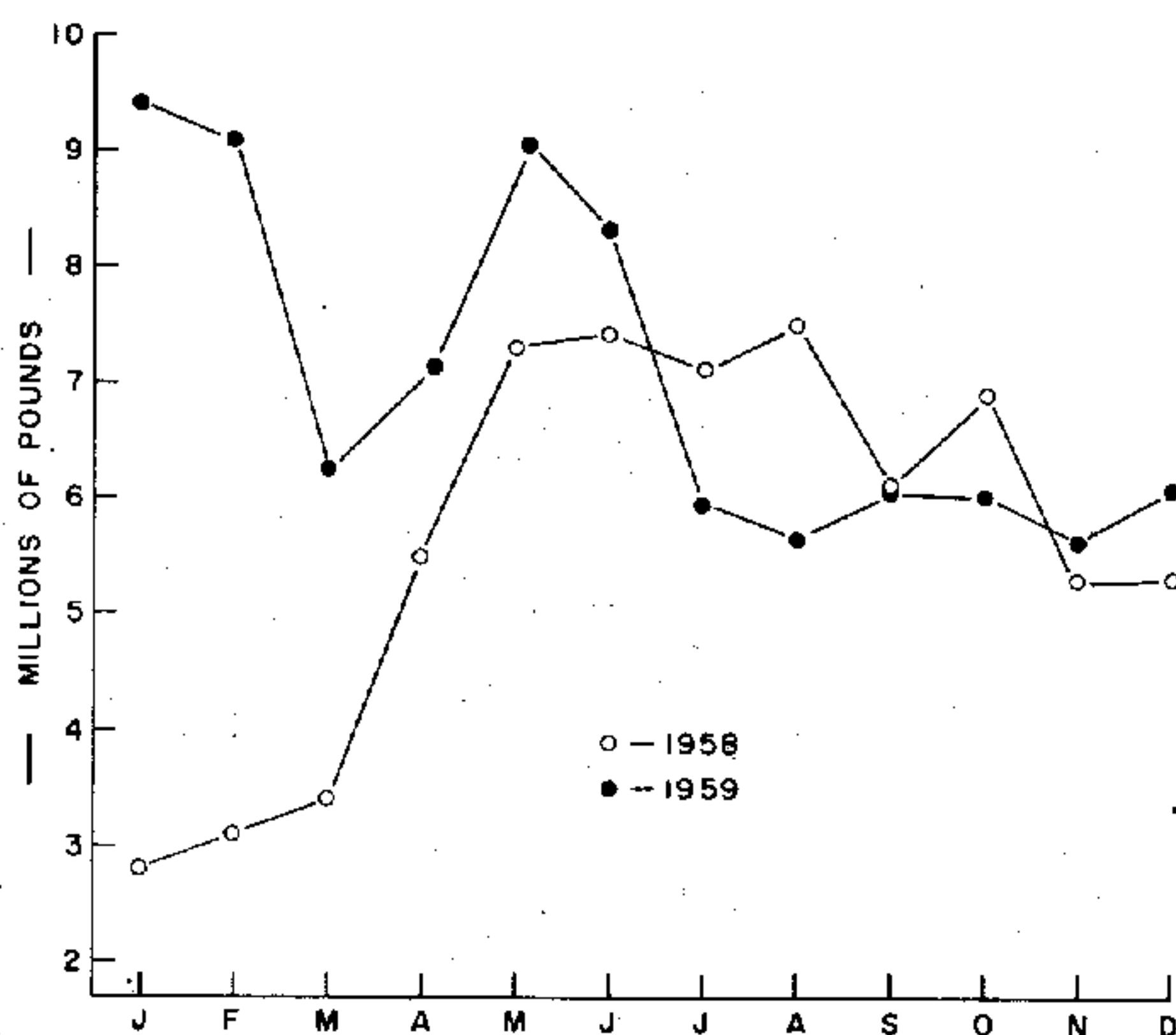
One of the many abundant and practically unexploited clupeoid species in the Gulf, the razorbelly, Harengula pensacolatae.

Trawl-Caught Industrial Fishes

Winthrop A. Haskell

The study of the trawl-caught industrial fish of the northern Gulf of Mexico concerns demersal species utilized for petfood and fish meal and has included: collection of statistics on the total number of landings and the total catch by month, determination of the species composition of the catch by weight and by numbers, and determination of the geographical and seasonal distribution of the more important species entering the industrial catch. Long-range objectives of the project are to observe and measure: (1) the direct effects of fishing on populations of fish exploited and (2) the indirect effects of that fishing on other marine populations in or near the areas fished.

Fishing grounds Geographical and seasonal distribution is being provided by information collected on areas and depths fished. Waters east of the Mississippi Delta provide approximately 67 percent of the catch. The area fished in summer is generally from just east of Mobile Bay, Alabama, to south of Chandeleur Island, Mississippi, in 2 to 7 fathoms. In winter many of the larger boats fish west of the Mississippi River in the area from about Empire to Ship Shoals, Louisiana. Depths fished in winter generally range from 8 to 20 fathoms but rarely deeper.



Monthly landings of trawl-caught industrial fishes for 1958 and 1959.

Landings The total catch and total number of landings for the calendar year of 1959 were generally lower during the winter months due to adverse weather conditions on the fishing grounds. Lowest monthly production was in November with a total of 5,638,000 pounds landed and the highest in January with 9,430,000 pounds. The total landed weight for 1959 was 84,778,000 pounds from 3,674 landings. The fishery may well top 100 million pounds in 1960 at its present rapid rate of growth. The trawl-caught demersal fish catch for 1958 and 1959 is shown on the graph in millions of pounds. Low production in March and October is explained by adverse weather conditions; low production from July to September reflects fewer plants operating during that period.

1959 Gulf of Mexico Industrial Fish Landings

1957 Gulf of Mexico Industrial Fishery				1958 Gulf of Mexico Industrial Fishery			
		Catch per vessel per trip ^{1/}				Catch per vessel per trip ^{1/}	
		Average				Average	
Month	All plants (-000)	Number of trips	catch (-000)	Month	All plants (-000)	Number of trips	catch (-000)
Jan.	9,430	150	31.2	July	5,934	198	24.1
Feb.	9,087	171	24.1	Aug.	5,667	193	26.1
Mar.	6,279	146	19.1	Sep.	6,010	210	26.9
Apr.	7,308	139	20.9	Oct.	5,902	233	22.0
May	9,075	149	21.6	Nov.	5,638	233	19.9
June	8,369	134	26.4	Dec.	6,081	205	21.9
					84,778	2,161	21.9

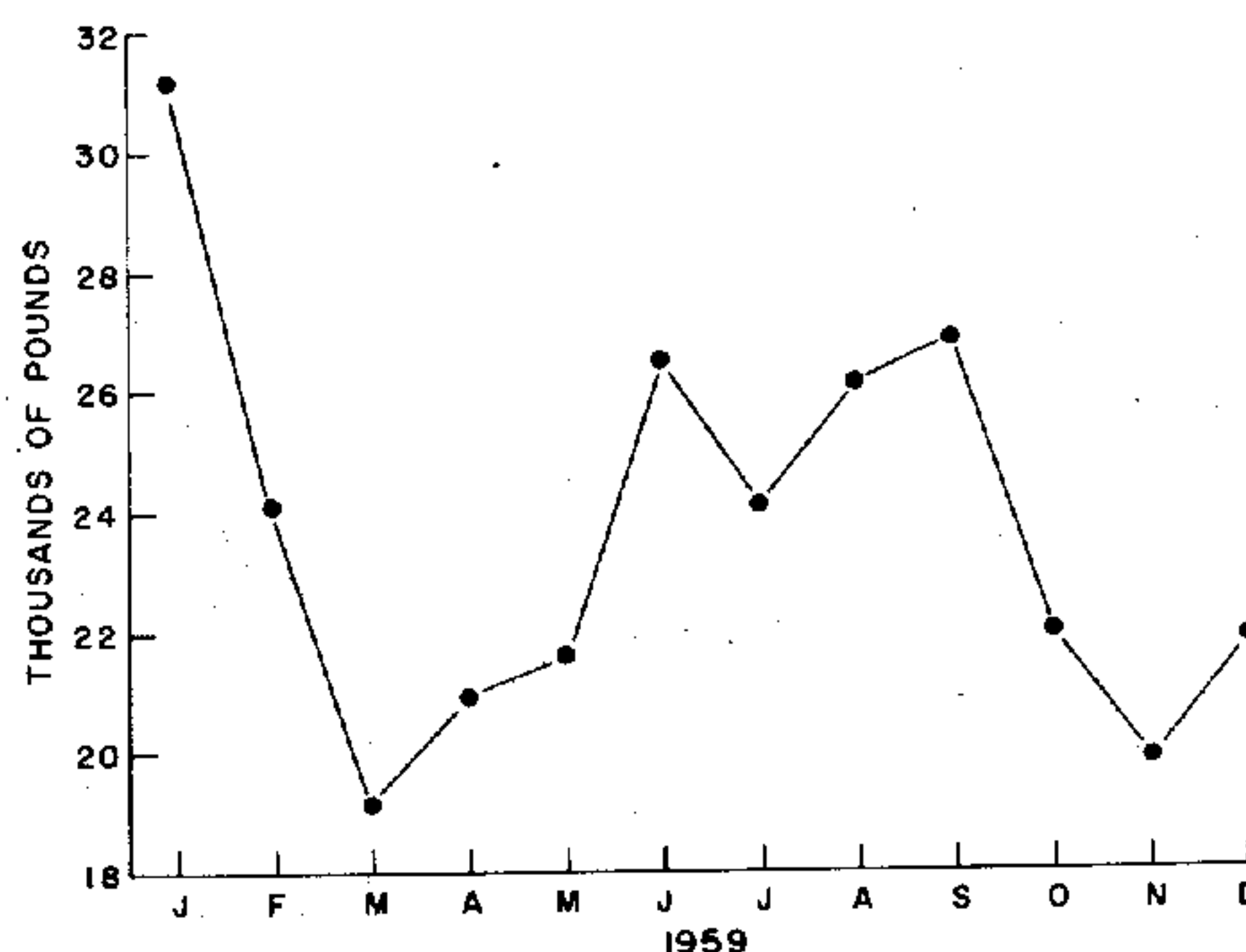
^{1/} For four Mississippi plants, their vessels made 2,161 out of the industry total of 3,674 trips.

Average catch per trip The accompanying graph shows for 1959 the average vessel catch per trip by months of vessels fishing for four petfood plants in Mississippi. The decline in March and again in November is due to adverse weather conditions. The rise from May to October reflects settled weather and availability of additional species generally absent during colder months as well as younger age classes of fish present in the shallower waters that are fished during the summer.

Species composition Since October 1958 intensive sampling was carried out in an effort to obtain samples from as many landings as possible. A total of 636 landings has been sampled in the past 18 months. In January 1960 sampling was reduced to as many landings as could be handled 2 days weekly. The additional time is being devoted to life history work.

About three-quarters of the average trawl catch consists of small croaker, (*Micropogon undulatus*); spot, (*Leiostomus xanthurus*); and white trout, (*Cynoscion nothus*). The fish are small, less than one-quarter of a pound apiece and in this respect are characteristic of catches in the area.

The majority of the species are from 5 to 8 inches in length. Very often even smaller fish are captured particularly in the shallower depth ranges of 2 to 4 fathoms often fished in summer.



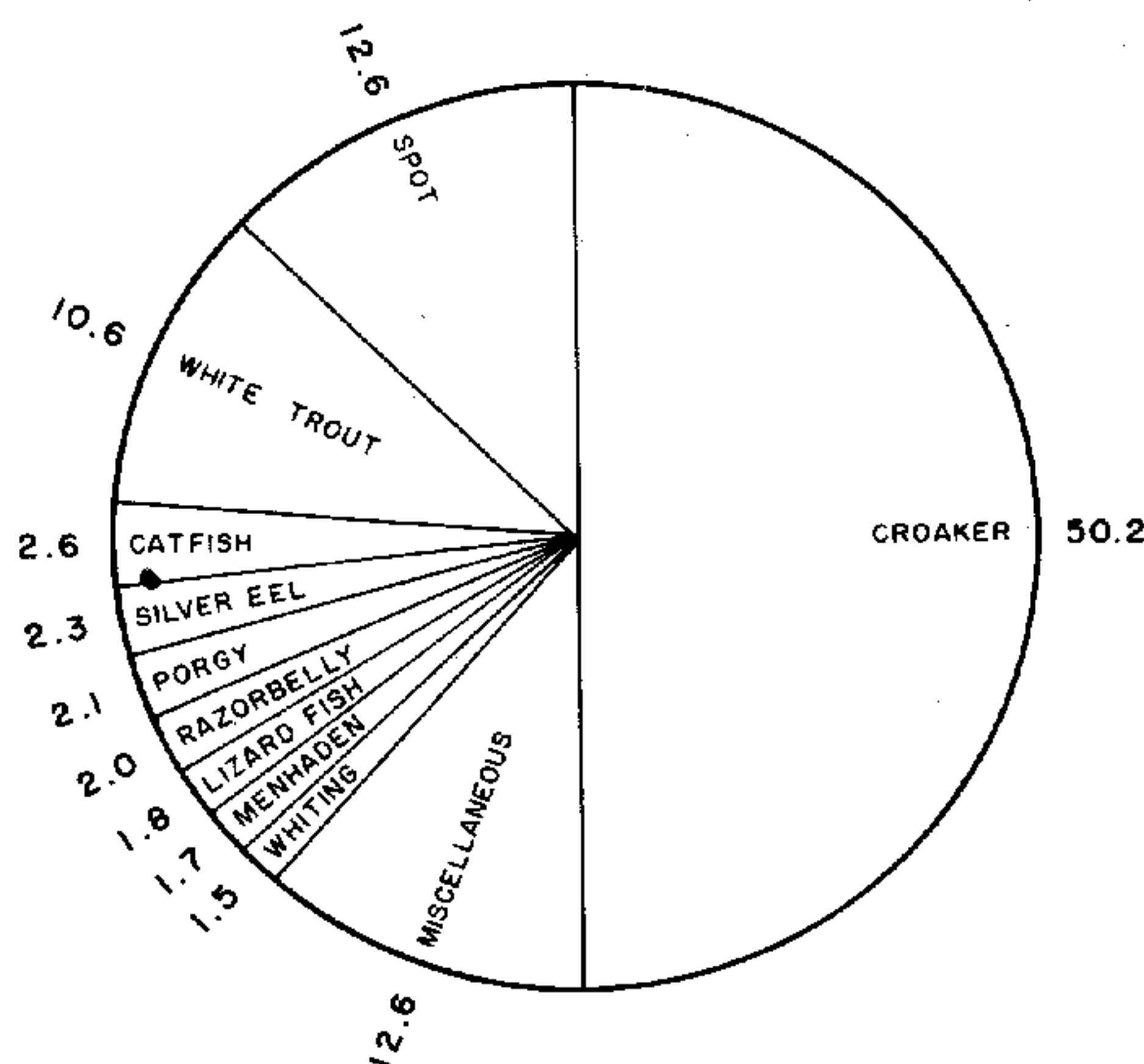
Average monthly catch per trip of industrial fish by trawlers of four Mississippi petfood plants during 1959.



Operations at an industrial fishery plant.

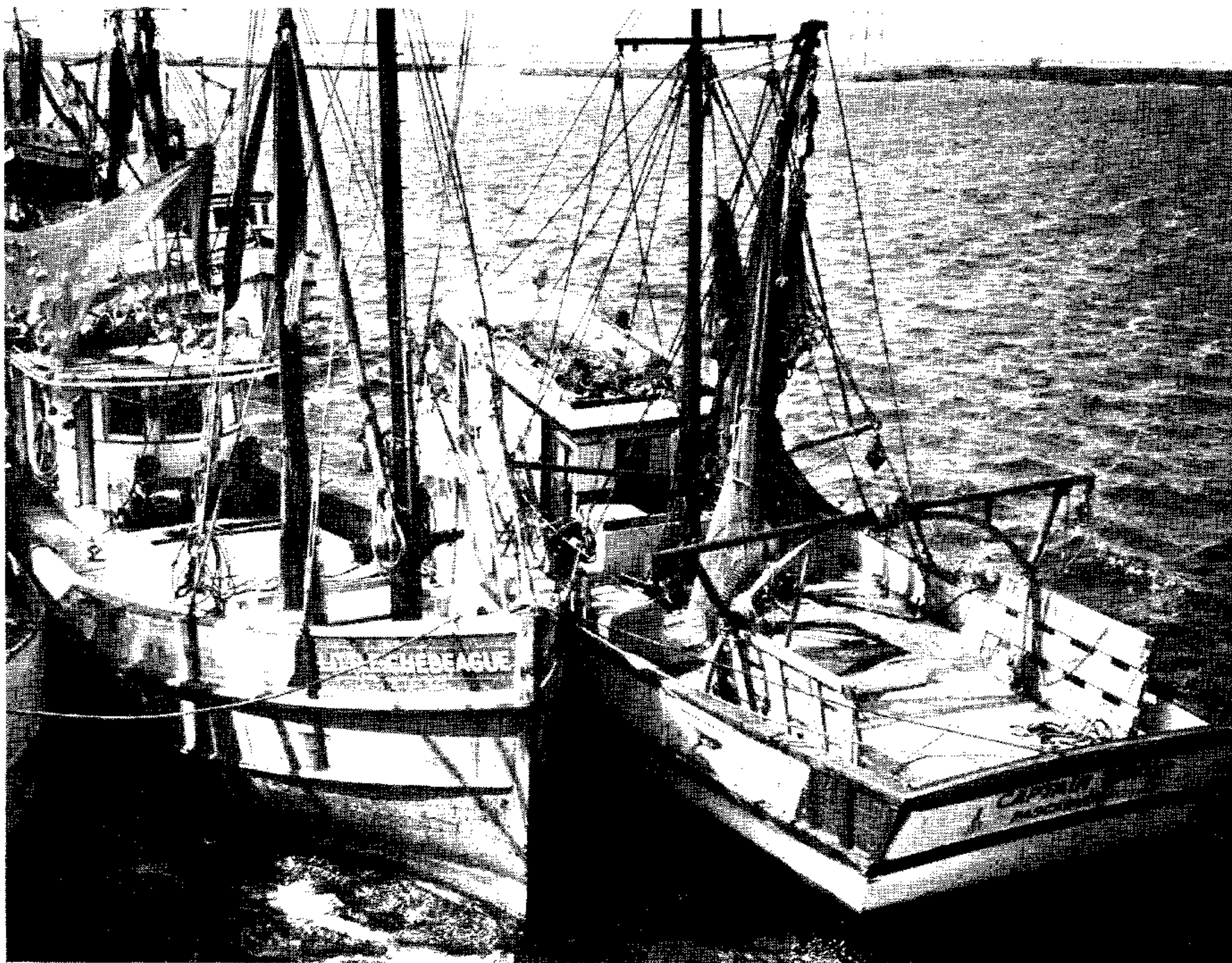
These three species, even when fully mature, do not often attain large sizes in Gulf waters and hence are unsuitable for either human consumption or sport fishing. The remainder of the catch is predominantly some 25 other species of demersal fish. The sampling has revealed that less than one-half of 1 percent of all fish landed are of species utilized for either food or sport.

The graph shows the species composition by percentage of total weight of the landings as determined by sampling. It will be seen that 12.6 percent is miscellaneous, consisting of species which appear rarely or in small numbers. This category includes such species as sharks, rays, skates, eels, and so forth. A total of 71 families and 170 species have been identified to date.



Species composition by weight of trawl-caught industrial fishes from January 1959 to April 1960.

Many species disappear during the colder months, probably migrating to areas outside those fished. These seasonal movements involve a number of species including razorbellies (Harengula pensacolatae), thread fin (Polynemus octonemus), and catfish (Galeichthys felis).



A single- and a double-rig trawler at a petfood plant.

Menhaden Populations

J. Y. Christmas, Jr.

Gulf Coast Research Laboratory, Dr. Gordon Gunter, Director
(Contract No. 14-19-008-9335)

This year's work on menhaden has been primarily directed toward the preparation of papers to be submitted as final reports on various phases of the menhaden project. Collection of material for life history and racial studies was continued.

Completed manuscripts "A Review of the Literature on Menhaden, with Special Reference to the Gulf Menhaden, Brevoortia patronus Goode" by Gordon Gunter and J. Y. Christmas brings together scattered sources of information. There are five North American species of Brevoortia. B. smithi inhabits both Atlantic and Gulf waters. The Atlantic menhaden fishery is dependent on B. tyrannus, and Gulf menhaden fishermen catch B. patronus. The literature revealed that B. tyrannus spawns at sea, or in high salinities, and the larvae move to low salinity waters. Spawning time apparently depends on water temperature and occurs off the South Atlantic states in winter, and in spring and summer farther north. Menhaden eggs and early larvae have not been reported from the Gulf of Mexico. Collections of larvae and juveniles indicate that B. patronus spawn in high salinities during the fall, winter, and spring. Larvae reach low salinity waters before metamorphosis. On the nursery grounds body proportions change from the larval form to the adult shape at about 30 mm. standard length, and the young fish move toward open, higher salinity waters in summer and fall. The number of young on the nursery grounds varies greatly from year to year. No long migrations of menhaden are known in the Gulf. There are little data on the growth rate of the Gulf menhaden.

B. patronus is known to feed by filtration and, in turbid estuarine waters, consumes considerable quantities of detritus and suspended bacteria in addition to living plankton. Bluefish, mackerel, sharks, and tarpon are the chief enemies of Gulf menhaden, and birds also take a toll. The common shore and shallow water sports fishes seem not to subsist to any great extent on larger menhaden, but predation upon small menhaden in the bays seems to be heavy. There is no evidence that menhaden are affected by fatal diseases in the Gulf of Mexico, but they are characteristically host to a number of worm and crustacean parasites. Reported studies show that few fish other than menhaden are taken by menhaden fishermen.

"A Study of Fishes Caught Around the Mouth of the Mississippi River and in Mississippi Sound in Menhaden Purse Seines" by Christmas, Gunter, and Whatley was completed. Preliminary conclusions of this paper were reported last year.

"The Distribution of Menhaden, Genus Brevoortia, in the Gulf of Mexico" by J. Y. Christmas and Gordon Gunter summarizes records on the distribution of menhaden in the Gulf and gives certain new information. Examination of specimens furnished by James Cating and Winthrop Haskell of the Pascagoula Laboratory of the U. S. Bureau of Commercial Fisheries resulted in extension of the known range of B. smithi and Brevoortia gunteri. The range of B. gunteri is extended from Grand Isle, Louisiana, to Chandeleur Sound, Louisiana, and the range of B. smithi is extended from Cedar Keys, Florida, to Chandeleur Sound, thus bringing three species of Brevoortia together. It is shown that B. patronus ranges almost symmetrically around the northern Gulf from Brazos Santiago, Texas, to Tampa Bay, Florida, growing up in estuarine areas and ranging into freshwater at smaller sizes. B. patronus also ranges into pure sea water, having been caught as much as 25 miles offshore and at a depth of 20 fathoms. B. gunteri and B. smithi have not been caught offshore in the Gulf at depths greater than 8 fathoms. These species have seldom been caught in the eastern and western parts of their respective ranges. Both enter freshwater at smaller sizes.

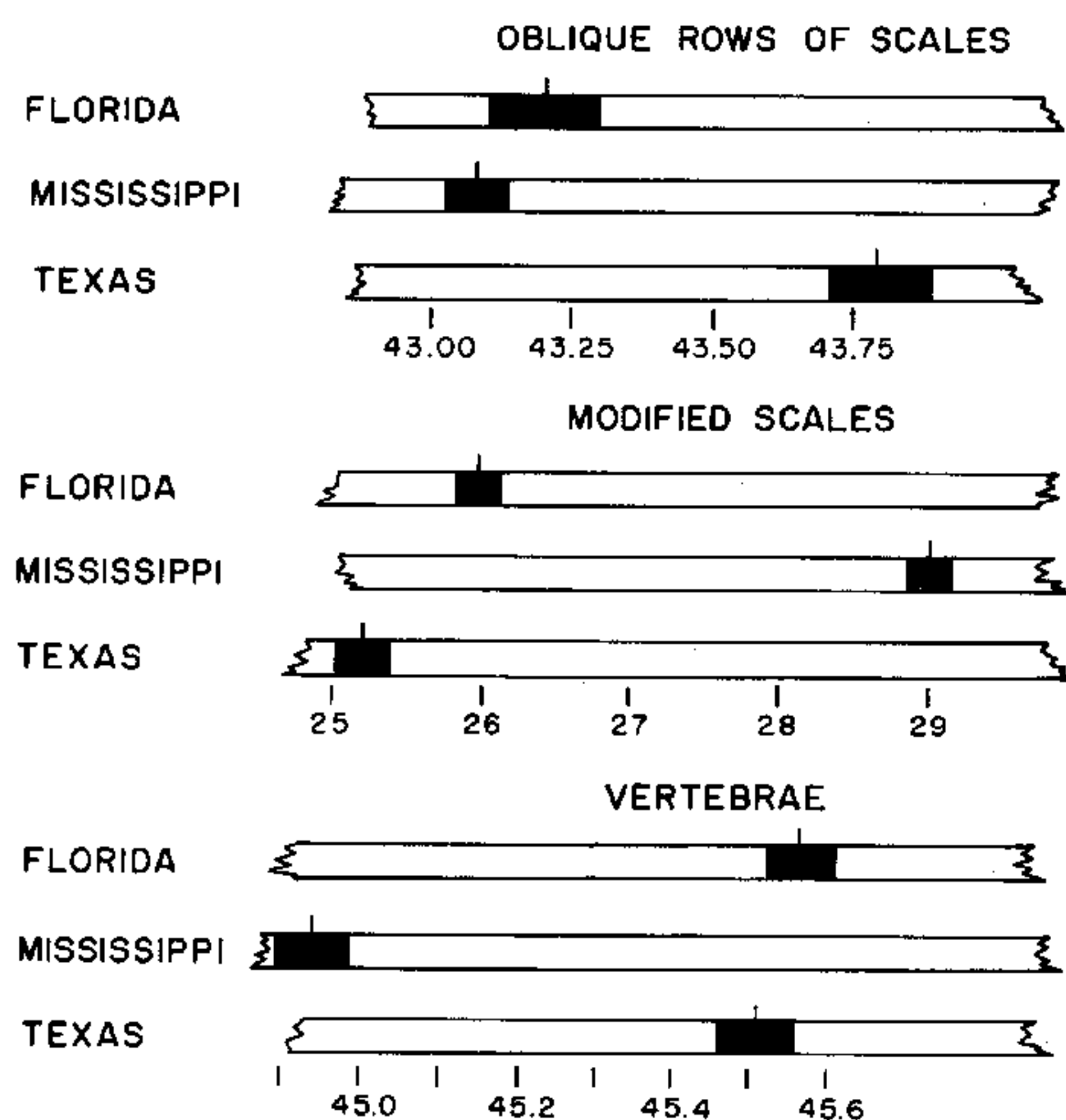
Racial studies Collection of meristic data for statistical analysis to determine whether there are discrete stocks of B. patronus in the northern Gulf of Mexico was started in September 1957. Since menhaden depend upon estuarine areas, as indicated by the presence of post-larval and young menhaden in low salinity bays, bayous, etc., and their absence in higher salinity Gulf waters during the summer, it seems that large river systems, causing estuaries, might support separate stocks.

Consequently, Apalachicola Bay, Florida; Mississippi Sound, Mississippi; and Sabine Pass, Texas, were selected as sampling areas. These areas are affected by different river systems, are separated geographically by many miles, and support a population of menhaden that justifies a commercial fishery. Since attempts to locate and catch spawning fish were not successful, the first samples from the selected areas were made up of the largest fish available during the fall, winter, and early spring of 1957-58. A fourth sample, caught off the Pass à la Loutre by the OREGON and consisting of fish that appeared to be near spawning, was included. Samples of young menhaden from these areas were taken between September 9 and 27, 1958. The mean fork length of the Mississippi sample is about 25 mm. greater than that of the Florida sample, and the Texas sample has a mean fork length about 4 mm. greater than that of the Florida sample.

At the end of September 1959 samples of young menhaden were collected from Apalachicola Bay, Florida; Pensacola, Florida; Mobile Bay, Alabama; Biloxi Bay, Mississippi; Lake Pontchartrain, Louisiana; Little Lake near La Fitte, Louisiana; Vermilion Bay, Louisiana; Sabine Lake, Texas; and Trinity Bay, Texas. All samples were taken from low salinity waters in a 10-day period and are composed of young B. patronus of approximately the same size.

Counts or measurements of 10 characters were recorded for 2,224 specimens from the first sampling. From these data 30 frequency distributions were tabulated and the following statistics determined: range, mean, mode, median, variance, and standard deviation, in preparation for comparison by regions. Results of comparisons by frequency polygons, confidence intervals for means, intergradation of samples, means of samples, variances, and skewness are significantly different in some characters, indicating that the samples were drawn from different stocks.

Five hundred specimens taken during one sampling period from each area were subjected to counts or measurements of the selected characters. Results of statistical comparisons of data from these samples show significant differences, indicating that there are different stocks of menhaden in the northern Gulf. The figure shows 95 percent confidence intervals for population means of certain characters of specimens examined from this sampling.



Comparison of scale counts and vertebrae of *Brevoortia patronus* caught in September 1958.

Meristic examination of approximately 1,800 specimens taken in another sampling has been completed. Analysis of these data will be made as soon as possible after completion of study of the remaining specimens.

Life history Although search for spawning menhaden was continued through the 1959-60 spawning season, they have not been located. Routine plankton sampling was continued through the year's spawning period. Samples of young fish and fish eggs have been removed from most of the plankton samples on hand. Clupeoid larvae and juveniles have been separated from the larval and juvenile fishes of other groups. Sampling of young of the year in estuarine areas is being continued. There seems to be an unusually heavy concentration of young in Mississippi waters this year. All menhaden from seine samples have been segregated, and many larval, post-larval, and juvenile samples have been measured.

ESTUARINE ECOLOGY INVESTIGATION

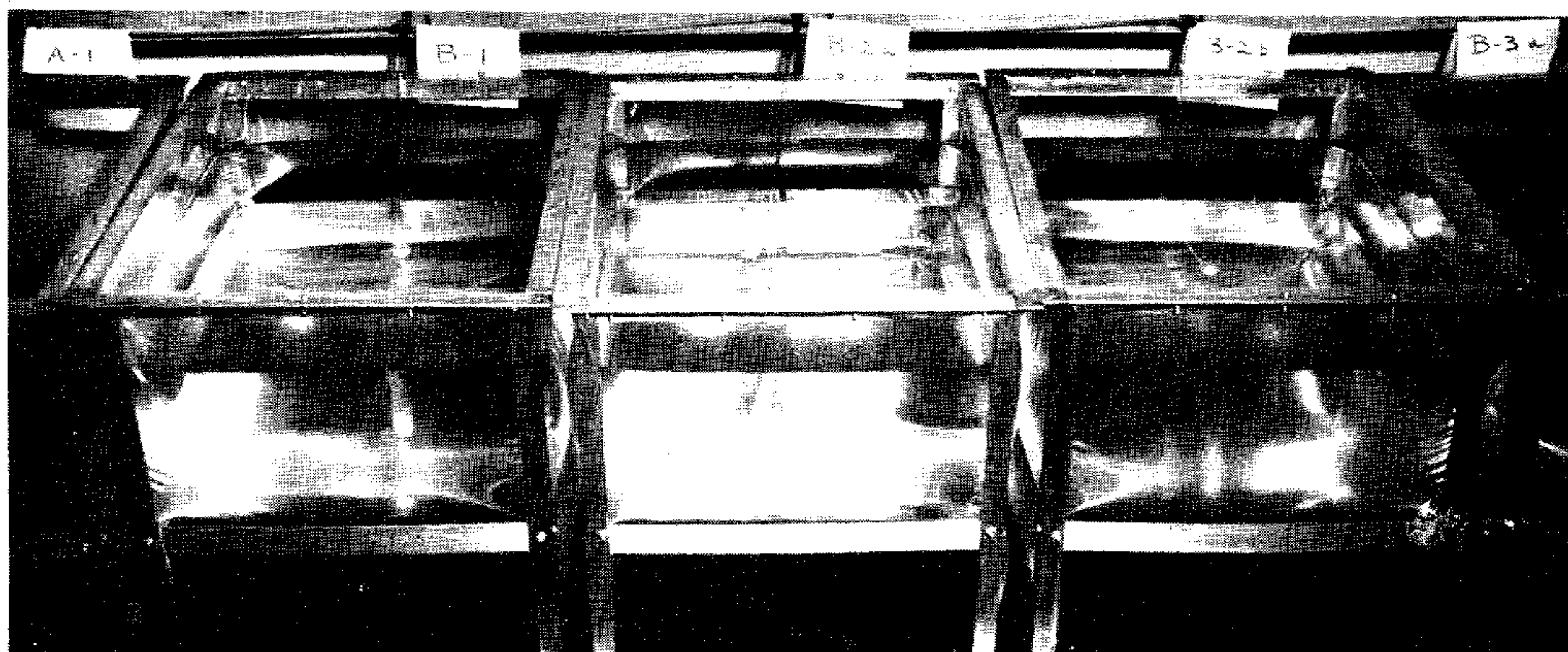
Edward Chin, Chief

Studies of seasonal cycles of shrimp populations in an estuarine area were continued in Clear Lake on a reduced scale to permit a comparative study in Offats Bayou. Offats Bayou, closer to the mouth of Galveston Bay, is of comparable size and more saline than Clear Lake. Unlike Clear Lake, it supports a sport fishery of some importance. Sampling of the fauna at a number of stations has begun with a shrimp trawl. Movements of brown shrimp from Galveston Bay studied by releasing stained shrimp in Clear Lake in May 1959 are presented in a following report.

Laboratory studies of the effects of salinity on growth and survival of shrimp were initiated because of need for factual knowledge on the possible effects of higher salinities that might occur in bays from reduced flows of freshwater. Seven recirculating systems containing seawater ranging in salinity from 2 to 40 parts per thousand have each been stocked with 450 post-larval shrimp. They averaged 12 millimeters in total length and were too small to identify positively, but are presumably brown shrimp.

An initial allotment enabled us to commence full-time studies of the effects of chemicals used as insecticides on a broad spectrum of estuarine and marine animals. Work carried on last year was preliminary in nature. The current program has been co-ordinated with studies of effects of insecticides on molluscs in Service laboratories at Gulf Breeze, Florida, and Milford, Connecticut.

Physiological differences between brown and white shrimp were studied in the allied fields of nutrition and respiration. We are developing a suitable artificial medium and artificial food, each containing known quantities of organics and inorganics. Studies on the normal respiration pattern of different sizes of shrimp of both species were continued to provide an index of the physiological condition of animals exposed to experimental media and fed synthetic diets.



100-liter disposable polyethylene aquaria on aluminum frames used in insecticide studies.

Insecticide Studies

Edward Chin

During the past year most of our efforts have been directed towards determining the relative toxicity of selected insecticides to species found commonly in the Galveston Bay area, particularly the two species of commercially important penaeid shrimp. Studies have been confined to the chlorinated hydrocarbons and thus far aldrin, benzene hexachloride, dieldrin, DDT, endrin, lindane, heptachlor, sevin, and toxaphene have been tested on some or all of the following species: white shrimp (Penaeus setiferus), post-larval and juvenile brown shrimp (P. aztecus), broad killifish (Cyprinodon variegatus), sailfin molly (Mollienisia latipinna), striped mullet (Mugil cephalus), spot croaker (Leiostomus xanthurus), longnose killifish (Fundulus similis), diamond killifish (Adinia xenica) and blue crab (Callinectes sapidus). Work with the organic phosphates, the other major group of chemicals used as insecticides, will be studied later.

The index of relative toxicity adopted is the median tolerance limit (TL_m); the concentration at which 50 percent of the test animals are able to survive for a specified period of exposure. Our standard method has been to hold all animals in the laboratory between 5 and 10 days prior to testing. Ten animals of uniform size are exposed to each of several concentrations of insecticide, and mortalities are noted periodically. Except when testing post-larval shrimp and crabs, the experimental aquaria used are 6-mil thick polyethylene liners supported by aluminum frames. Inside dimensions of the frames are 23 inches long by 17 inches wide by 18 inches high. One hundred liters of test solution are used, and the liners are discarded after each test to avoid the problem of contamination. Although fish are allowed to swim freely, shrimp, due to their cannibalistic tendencies, are placed individually within glass chimneys (Coleman lantern type) covered at the ends with perforated polyethylene film.

Five insecticides have been tested on white shrimp ranging from 75 to 130 millimeters in length, and thus far DDT is the most toxic as shown by a 24-hour TL_m of 15 parts per billion. It was followed by sevin (33 p.p.b.), heptachlor (43 p.p.b.), and dieldrin (60 p.p.b.). The value for aldrin is under 50 parts per billion.

Of six insecticides tested on juvenile brown shrimp ranging in length from 37 to 70 millimeters, endrin was the most toxic with a 24-hour TL_m of 5 parts per billion. Following closely behind were lindane (8 p.p.b.), dieldrin (10 p.p.b.), heptachlor (20 p.p.b.), and sevin (27 p.p.b.). Toxaphene, relatively much less toxic, yielded a 24-hour TL_m of 100 parts per billion. The value for aldrin is less than 100 parts per billion.

Tests with post-larval shrimp (apparently brown shrimp) ranging from 12 to 16 millimeters in length, were conducted in 250 milliliter reagent bottles. This size group of shrimp is so small that it would be

difficult to observe them in the 100-liter vessels ordinarily used. However, the primary reason for using reagent bottles is that small shrimp under stress often flick out of the water and become fixed to the sides or tops of vessels unless the vessel is filled to capacity. The reagent bottles were divided in groups of 10. Each group was filled with a test solution, and one shrimp was placed in each bottle. Thus the volume of test solution per shrimp was 0.25 liter compared to the 10 liters in the plastic vessels.

Of the four insecticides tested thus far on post-larval shrimp, endrin and lindane were particularly toxic, as reflected by 24-hour TL_m values of 0.5 and 2 parts per billion, respectively. In less than 48 hours 100 percent mortality occurred at concentrations of 0.3 parts per billion (endrin) and 2 parts per billion (lindane). Heptachlor and dieldrin were only slightly less toxic with 24-hour TL_m values of 11 and 15 parts per billion respectively. Post-larval shrimp deserve particular attention because they are commonly found in the brackish, upper waters of the estuarine systems and would be, therefore, the size group most likely to be affected by chemicals washing out from treated areas.

Endrin is probably not only the most toxic of the insecticides to shrimp but also to fish. The sailfin molly had a 24-hour TL_m value of 2.5 parts per billion for endrin compared to between 10 and 25 parts per billion for dieldrin and between 50 and 100 parts per billion for heptachlor. In fact, endrin has replaced rotenone as a fish toxicant in some areas in the Orient because of its lower cost and efficiency.

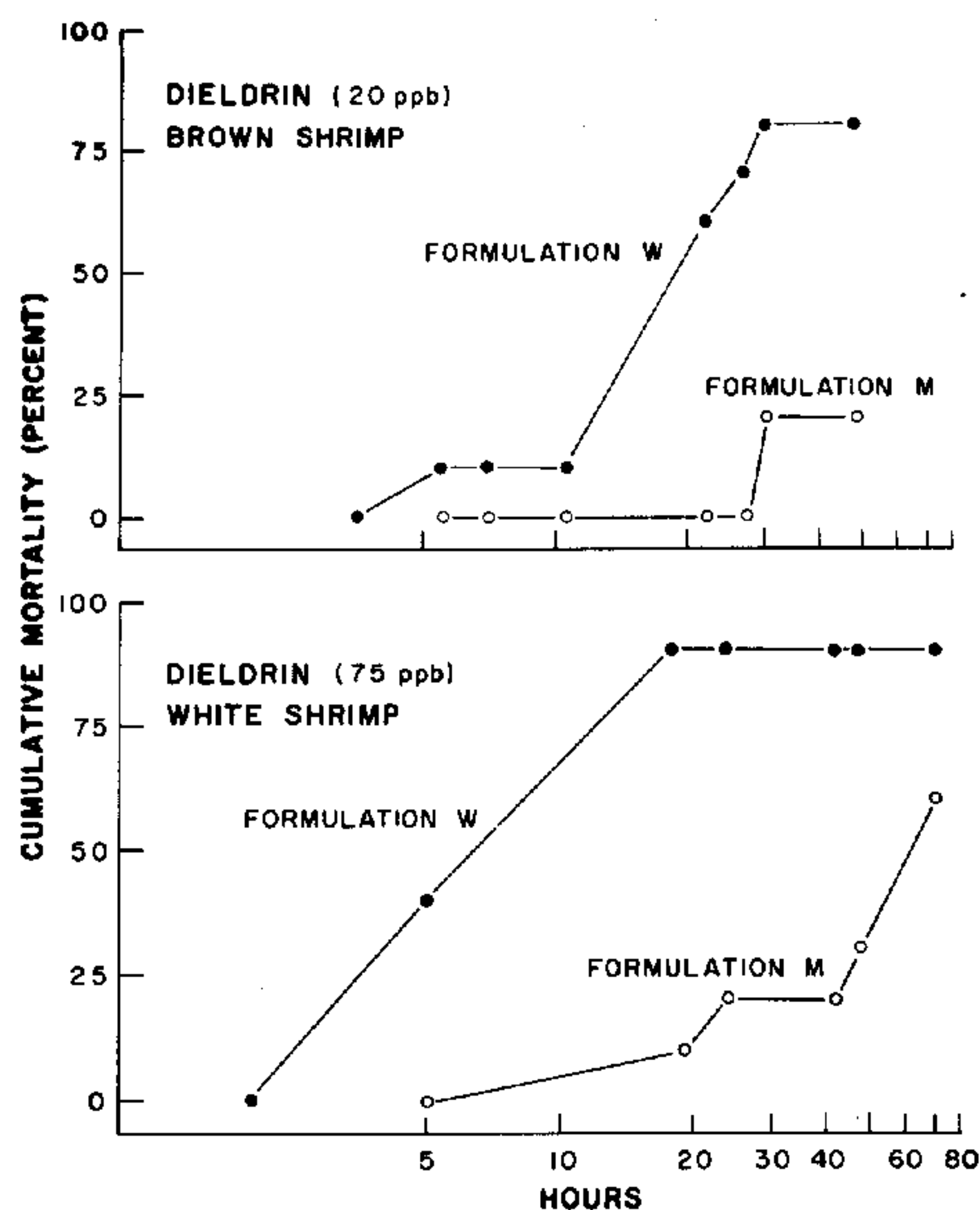
Heptachlor and dieldrin, two insecticides used commonly to control the fire ant, have been tested on a number of fish species as well as shrimp, and the results to date are shown below:

Species	Heptachlor		Dieldrin	
	Avg. length	24-hr. TL_m	Avg. length	24-hr. TL_m
Brown shrimp	14 mm.	11 p.p.b.	13 mm.	15 p.p.b.
Brown shrimp	50	20	46	10
White shrimp	86	43	96	60
Spot croaker	82	25-50		
Sailfin molly	42	50-100	43	10-25
Broad killifish	42	143	35	< 50
Diamond killifish	25 (approx.)	150		
Longnose killifish	77	250		
Striped mullet	117			20-50

The TL_m values cited above are necessarily considered tentative for a number of reasons. Criteria for death require re-evaluation, particularly in regard to shrimp, which are somewhat less than ideal as bio-assay organisms. In our studies animals are not considered dead until no movements can be detected and no reaction can be elicited by tactile

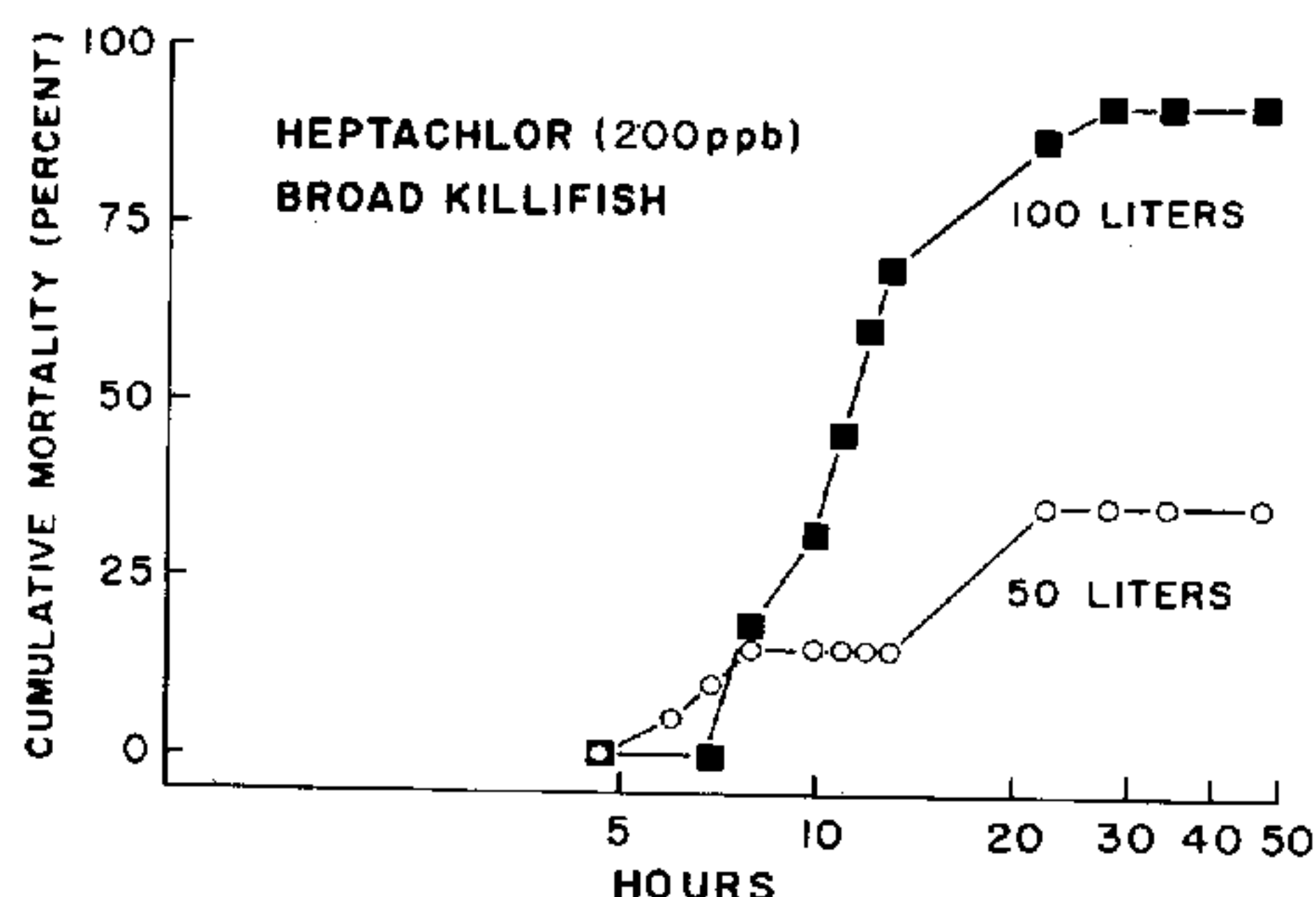
stimulation. The species of fish tested thus far pose no problem in this respect because either death or recovery follows not long after a period of stress. For shrimp the period of stress is prolonged, and individuals often remain on their sides or backs in an apparently moribund stage for many days. The only indication of life is an occasional feeble fluttering of the pleopods or movement of the walking legs. Very few of them recover even when transferred to clean sea water at the end of an experiment. Blue crabs remain even longer in a state of moribundity; the only evidence of life is an occasional slight movement of the maxillipeds or antennules. With animals that exhibit this type of reaction, stress patterns require adequate description to define the stage or stages beyond which an animal should be considered dead from a practical viewpoint.

A major factor determining the TL_m values for a basic chemical used as an insecticide is the vehicle which includes combinations of various emulsifiers, petroleum hydrocarbons, inert ingredients such as clays, and varying proportions of "related compounds." For each basic insecticide, there are numerous formulations on the market. An example of the difficulty in comparing results using different formulations is shown in an accompanying figure. Equal concentrations of dieldrin made with two formulations showed differential toxicity to both species of shrimp.



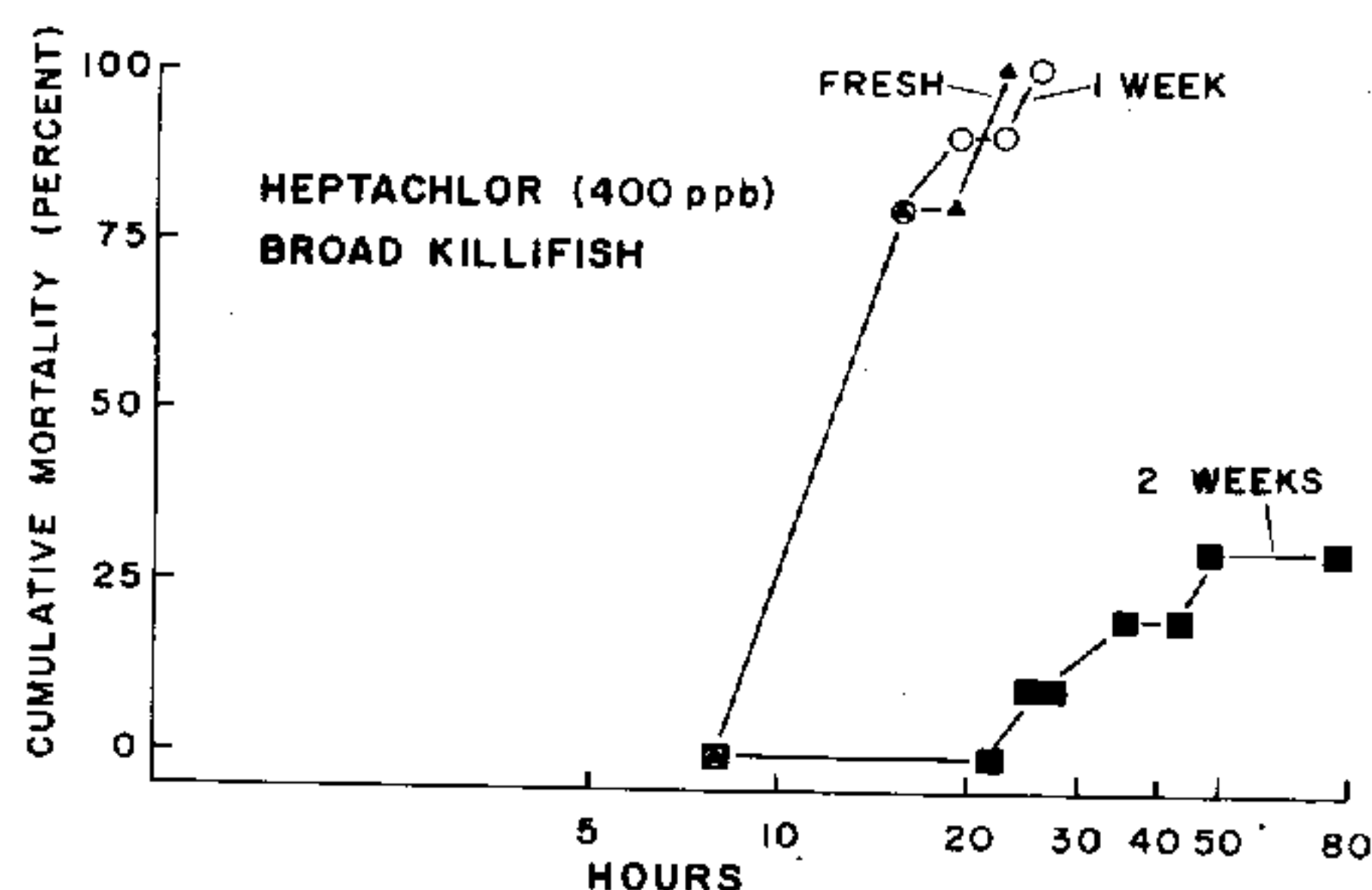
Differences in toxicity between similar concentrations of dieldrin made with different formulations.

Other factors affecting the nature of bioassay results deserve mention. Earlier investigators have recommended that an optimum volume of test solution be determined for each toxicant prior to actual testing because at equal concentrations the toxicity of a test solution increases with increasing volume, at least up to a certain level. We chose 100 liters as a standard volume (except for post-larval shrimp) to avoid this problem. Although we have found indications that with some insecticides the optimum volume is in excess of 100 liters, it is impractical to work with a larger volume in the laboratory. Comparison in an accompanying figure of the toxicity of 50 and 100 liters of a 200 p.p.b. solution of heptachlor to the broad killifish, clearly demonstrates this phenomenon.



Differences in toxicity between different volumes of test solution, using the broad killifish, Cyprinodon variegatus.

Age of the stock solution has a pronounced effect on its toxicity and has resulted in discarding of some of our initial results. With all of the insecticides tested thus far, there is a significant reduction in toxicity with age, an important factor in the consideration of potential damage caused by insecticide residues. Differences in toxicity to the broad killifish of three stock solutions of heptachlor, 0, 1, and 2 weeks old, are shown in an accompanying figure.



Differences in toxicity between stock solutions of different ages, using the broad killifish, Cyprinodon variegatus.

Nutrition and Respiration

Zoula P. Zein-Eldin

In studying nutrition of land animals those fed a known diet are compared with those fed a diet deficient in a given nutrient. In marine forms similar studies share a common problem - definition of the medium in which they live. Natural sea water is a complex mixture varying with the time and place of its origin. Thus, it is necessary to find a satisfactory artificial medium as a substitute. This creates an additional problem - that of establishing criteria for the suitability of the medium. In protozoa, dinoflagellates, etc., multiplication of a culture may be used as a criterion, and in higher forms the growth of the test animal as compared to animals in natural sea water. In crustacea, growth is closely associated with molting - a process which may cause severe stress. Thus, the medium chosen must be one which will permit survival of the animal through several molts and allow dietary deficiency symptoms to be produced.

Artificial sea water media containing only sodium chloride, potassium chloride, magnesium chloride, magnesium sulfate, and calcium chloride were used initially. The calcium ion was found to be extremely important; both Penaeus aztecus and P. setiferus died within 48 hours when the ion was absent or the concentration reduced to one-half that commonly found in sea water. Subsequently the calcium ion concentration has been maintained at that found in standard sea water, even when the salinity of the medium is reduced. In such a medium white shrimp (P. setiferus) fed natural foods (e. g. - liver, fish shrimp, wheat germ, and oatmeal) survived a single molt but died either during the succeeding intermolt or at the second molt. This species developed an interesting pathological lesion (found rarely in animals held in the laboratory in natural sea water). A fluid-filled blister formed between the membranous layers of the carapace covering the ventral section of the gills and, as the carapace hardened, the fluid within the blister darkened. Over 50 percent of the animals showed this symptom at the second molt; many animals were unable to complete the molt, perhaps because of the pressure exerted by the fluid upon the gill tissues. Although the cause of this deficiency is not known, the absence of these blisters is being used as the criterion for adequacy of the medium.

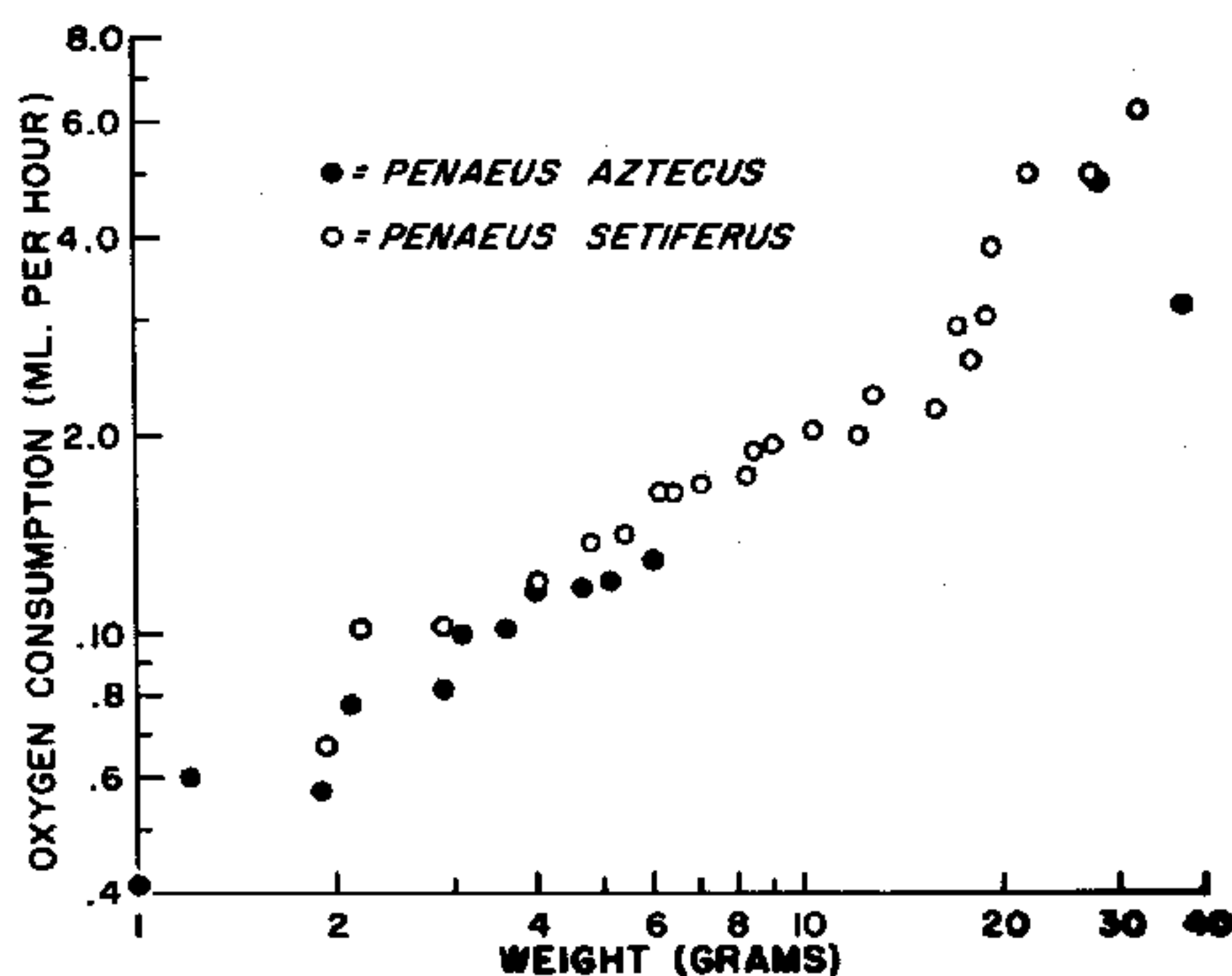
Some shrimp are being fed an artificial diet of casein, gelatin, purified sugars, vitamins, and trace elements. Preliminary results indicate a difference in the intermolt period between those fed an artificial diet and those fed a natural diet.

Experiments indicate a requirement for certain trace elements. In an artificial medium enriched with a trace element mixture containing cobalt, zinc, iron, copper, aluminum, and manganese, 60 mm. brown shrimp (P. aztecus) have survived two molts whereas 40 mm. shrimp of the same species in a medium lacking the trace elements have shown a pathological lesion after

the first molt. The lesion, like that in white shrimp, occurs in the ventral section of the carapace, immediately over the gill. Blisters do not form and the affected section of the carapace is soft and floats freely in water. Other shrimp, not showing the lesion, have nevertheless died during molt and characteristically have failed to cast the exoskeleton immediately ventral to this portion of the carapace. Certain of the trace elements are apparently essential to molting - in particular to hardening of the exoskeleton.

Brown shrimp in enriched artificial sea water show similar differences in intermolt period between animals fed natural and artificial diets. Greater differences occur between animals in natural and artificial sea water. After a period of 2 weeks, brown shrimp in artificial medium have molted twice while not all of those in the natural sea water have molted once. Thus the artificial medium appears to be exerting a molt-stimulating influence. In artificial sea water there are indications of a longer survival period for those animals fed an artificial diet than for those fed a natural diet; this was true for two size groups of brown shrimp, 25 and 60 millimeters in length.

Studies of respiration (oxygen uptake) have been made for 67 white and 44 brown shrimp, ranging in weight from 0.4 g. to 40.4 g. Individuals were tested for at least 5 hours under the standard conditions (22°-23° C. and 16 hours acclimation to sea water); more than half the animals were tested for 15 to 25 hours. Total oxygen consumption ranges from 0.50 ml. O₂/hour for the smallest animal tested (a 0.4 g. white shrimp) to 6.29 ml. O₂/hour for a 32 g. white shrimp and is significantly correlated with size. Expressed as oxygen consumed per gram weight per hour these values would range from 1.23 ml. /g. /hr. for the smallest animal to only 0.20 ml. /g. /hr. for the large animal mentioned. This follows the general rule that metabolic activity decreases with increasing size. The greater oxygen consumption per gram weight of the smaller animals is an indication of greater food requirements per unit weight for smaller as compared to larger individuals. The relationship between food requirements and increased oxygen does not hold, however, at the molt period; immediately before and after the molt oxygen consumption increases greatly (e. g., one 20.5 g. white shrimp increased its oxygen uptake from 2.51 to 4.50 ml. /hour despite lack of food).



Field Studies

Edward Chin and Anthony Inglis

Field studies have been carried on at Clear Lake since January 1958 to describe and analyze the seasonal cycles of populations inhabiting the lake, with particular reference to the two species of penaeid shrimp known to occur there. During the past year the sampling program was reduced to permit the initiation of other projects. The data collected during 1959 have not been fully analyzed yet and the following remarks are based on the first year's data.

In the samples, taken by means of a shrimp trawl, 41 species of fish and 3 species of invertebrates were taken. From the size frequencies obtained, nearly all specimens were substantially below adult sizes. The 44 species were separated into four groups based on the total number of each species taken during the year. Some species, such as the anchovy and menhaden, are admittedly less susceptible to capture by a trawl, and any grouping of species by total number taken is subject to valid criticism. Nevertheless, grouping is convenient for purposes of discussion.

Only seven species were taken in sufficiently large numbers to be considered as major species. These were:

Golden croaker (<u>Micropogon undulatus</u>)	17,380
White shrimp (<u>Penaeus setiferus</u>)	13,840
Brown shrimp (<u>P. aztecus</u>)	7,123
Gulf menhaden (<u>Brevoortia patronus</u>)	2,846
Southern bay anchovy (<u>Anchoa mitchilli</u> <u>diaphana</u>)	2,726
Blue crab (<u>Callinectes sapidus</u>)	2,144
Spot croaker (<u>Leiostomus xanthurus</u>)	1,600

Six taken in lesser numbers were considered as minor species:

Sand squeteague (<u>Cynoscion arenarius</u>)	674
Hardhead catfish (<u>Galeichthys felis</u>)	321
Southern flounder (<u>Paralichthys lethostigma</u>)	272
Gafftopsail catfish (<u>Bagre marina</u>)	266
Hogchoaker (<u>Trinectes maculatus</u>)	224
Spotfin whiff (<u>Citharichthys spilopterus</u>)	150

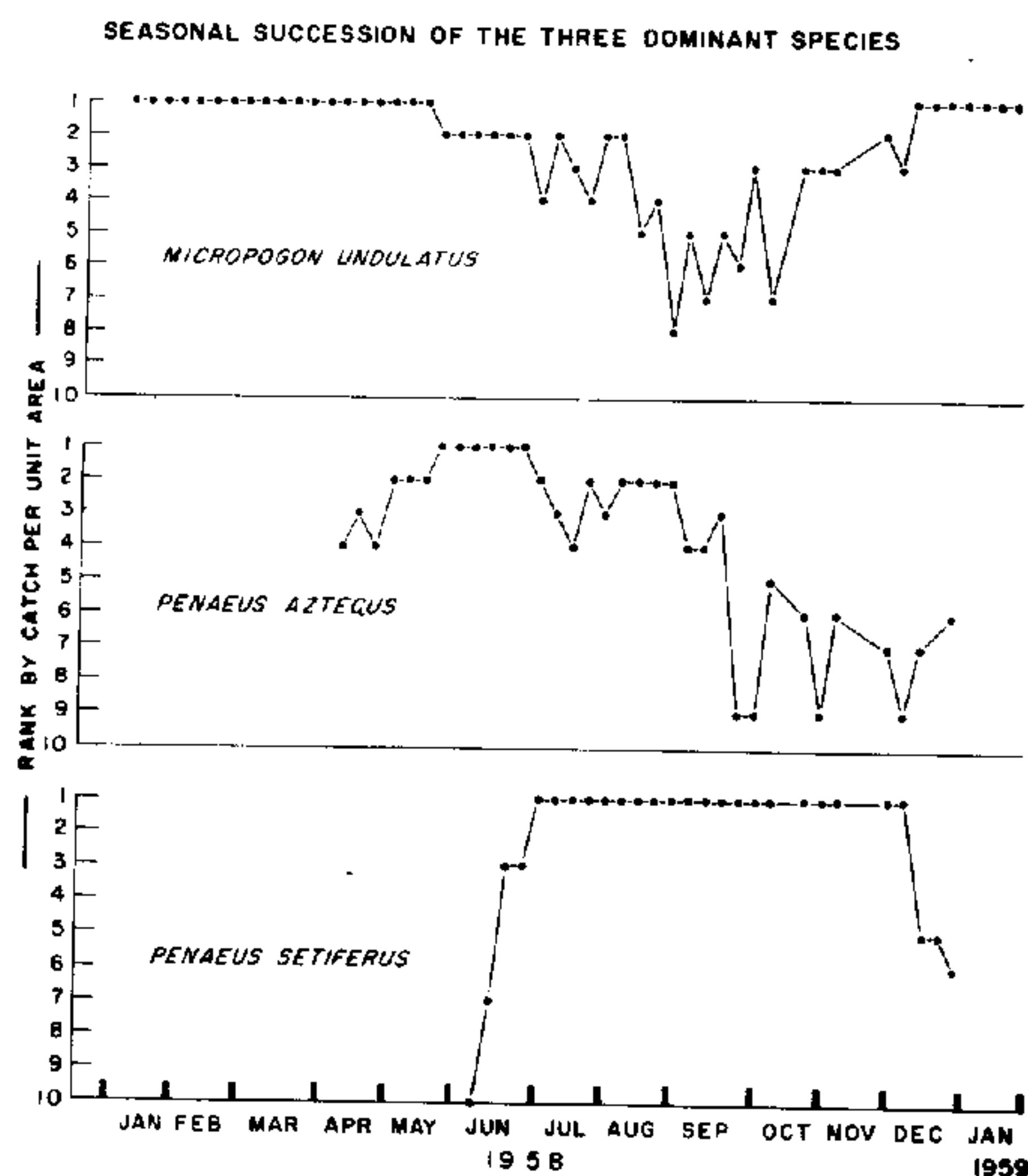
Eight species, taken in total numbers ranging from 21 to 70 were termed uncommon, and the remaining 23 species taken in numbers from 1 to 11, were considered rare.

Three species (golden croaker, white shrimp, and brown shrimp) clearly dominated the populations sampled by the trawl. In terms of total numbers, they formed almost 70 percent of the total catch of nearly 50,000 specimens. Ranking each species according to its relative abundance each week showed that throughout the year, these same three species monopolized the position of the most abundant species.

The index of relative abundance adopted was the catch per unit of area, the unit of area being 1100 square yards. All species were ranked each week according to the catch-per-unit area so that the species with highest catch per unit ranked first, the next second, etc. Weekly changes in rank, shown in an accompanying figure for the three dominant species, clearly demonstrate a distinct pattern of seasonal succe-

sion. From the beginning of the study in January until the middle of May, the golden croaker held the position of the most abundant species. Brown shrimp which ranked fourth with its initial appearance in April samples, rose rapidly to the second position in May, and supplanted the golden croaker as the dominant species by the end of May. During June the first and second positions were occupied by the brown shrimp and golden croaker, respectively. The white shrimp, first noted in early June, ranked 10th initially, but rose to the 3rd position by the end of June and to the 1st position at the beginning of July. From July until mid-December, the first

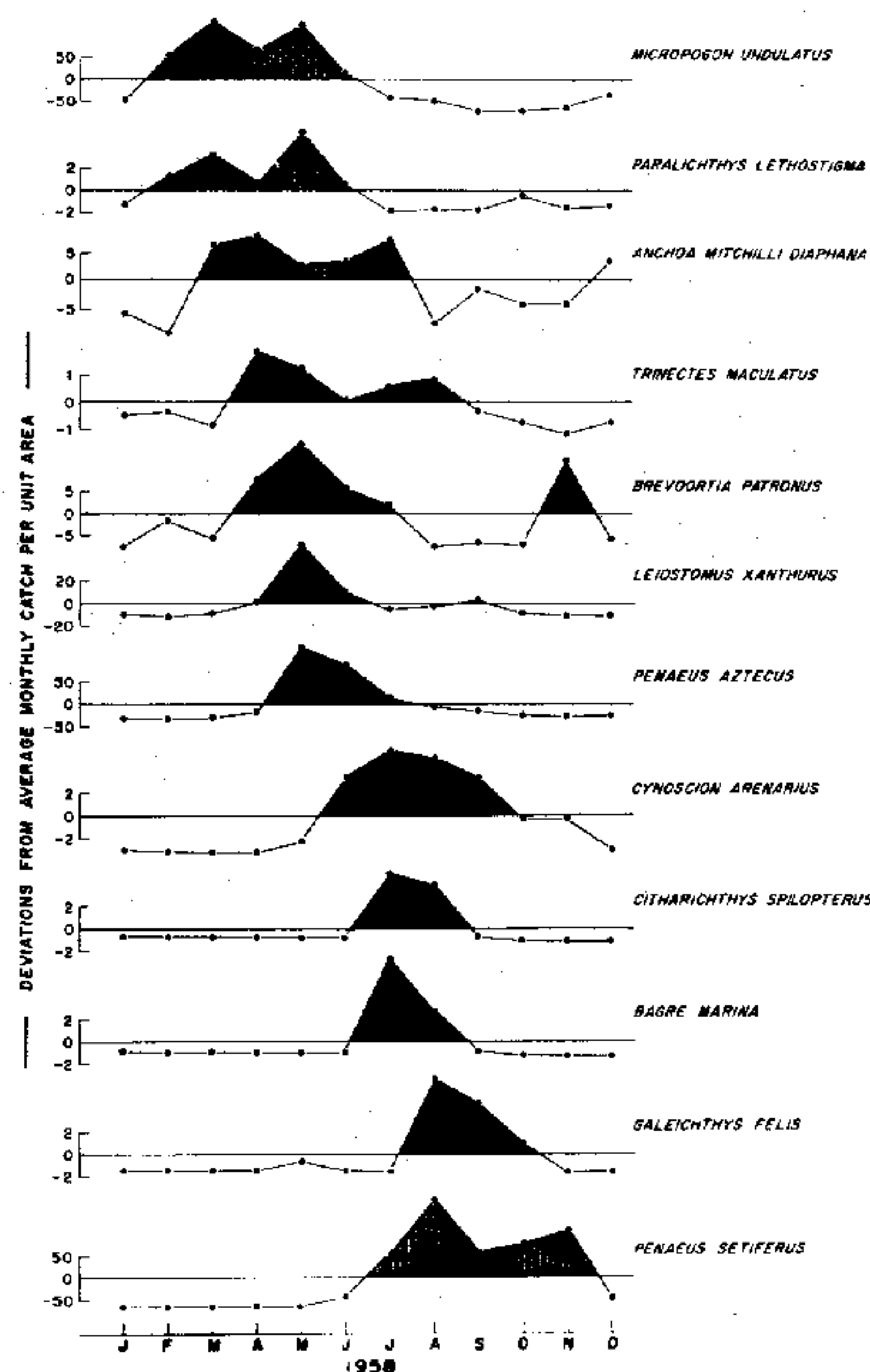
position was held exclusively by the white shrimp. During July and August brown shrimp and golden croaker, displaced by the white shrimp, fell to second and third places, respectively. The brown shrimp continued to drop in relative abundance in September, and by October, it had fallen below fourth position. The relative abundance of the golden croaker also dropped to a seasonal low in September. In October, however, as the first recruits of the new-year class appeared in the trawl samples, the golden croaker began to increase in relative abundance and in December, coupled with the disappearance of white shrimp from the lake, regained first place as the most abundant species.



The seasonal succession of other groups of species is indicated in an accompanying figure which shows monthly deviations from the average monthly catch-per-unit area for selected species. Changes in the relative abundance of the golden croaker (Micropogon undulatus) and the southern flounder (Paralichthys lethostigma) show almost identical trends, with the major period of abundance from February through May.

The anchovy (Anchoa mitchilli diaphana) appears to be most abundant beginning in March and continuing through July (bearing in mind the limitations of the trawl in sampling this species). The major period for the hogchoker (Trinectes maculatus) appears to be from April through August. Three major species, menhaden (Brevoortia patronus), brown shrimp (Penaeus aztecus), and spot croaker (Leiostomus xanthurus), then follow closely. Except for the high value recorded in November for menhaden, the trends were similar for all three species; the peak month of abundance was May. The sand squeteague (Cynoscion arenarius) occurred mainly from June through September with a peak in July.

Two species, the spotfin whiff (Citharichthys spilopterus) and the gafftopsail catfish (Bagre marina), had a limited seasonal distribution, occurring only in July and August. The hardhead catfish (Galeichthys felis) also had a limited seasonal distribution, from August through October. White shrimp (Penaeus setiferus), as already noted, occurred extensively, with the major period lasting from July through November.



RED TIDE INVESTIGATION

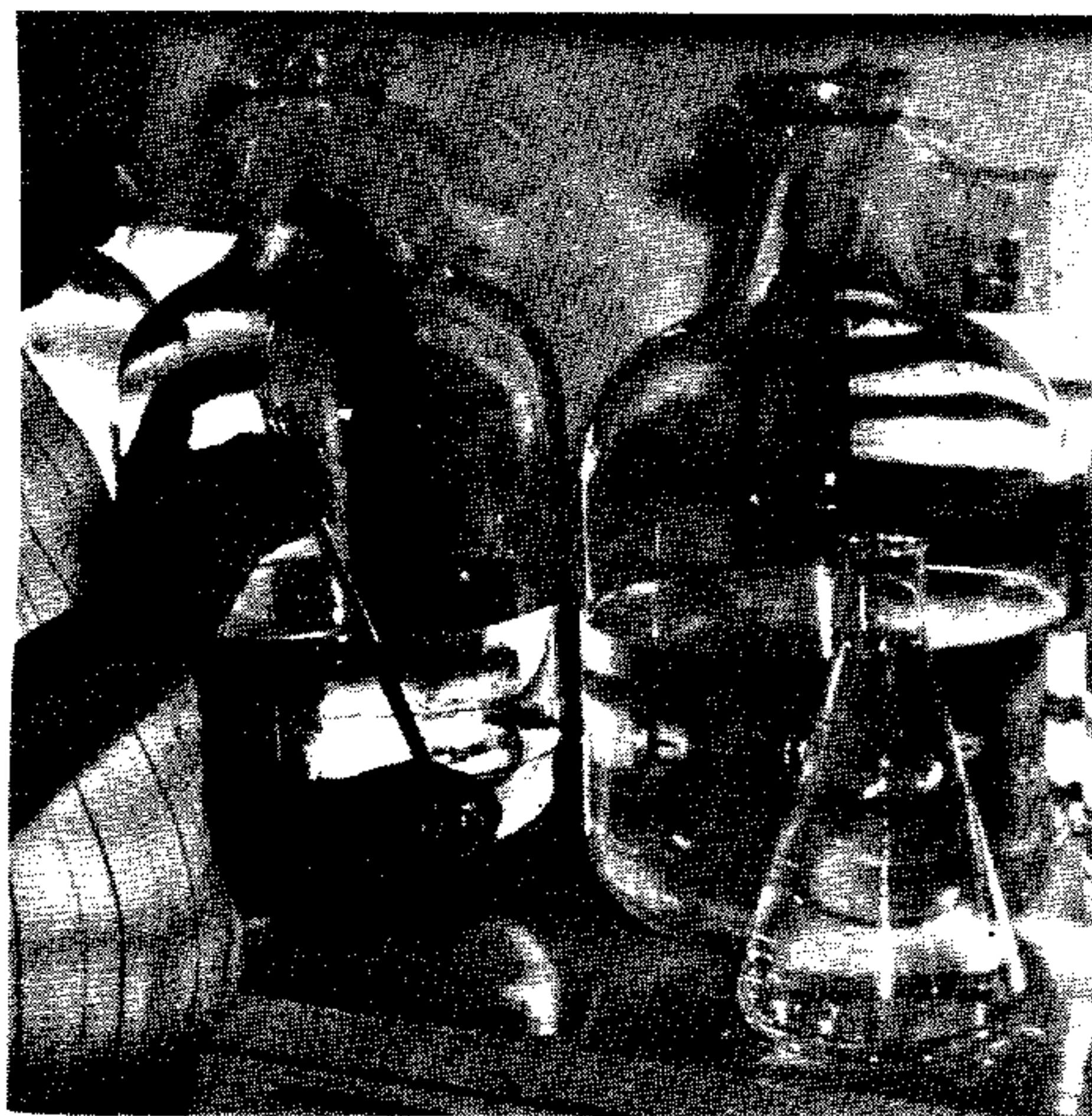
William B. Wilson, Chief

In a year marked by heavy rainfall large numbers of the red tide organism, Gymnodinium breve, and some fish mortality, the methodical planning which produced the field study project for Tampa Bay and adjacent Gulf waters has shown its value. This systematic sampling program is providing the most informative series of data on record with respect to the hydrographic and planktonic conditions within a red tide area. The complex sequence of hydrographic events preceding, accompanying, and following red tide outbreaks has never been clearly defined. The Tampa Bay area field project represents an essential first step toward obtaining this type of information.

Several new environmental factors are now being followed -- alkalinity, total nitrogen, calcium, and silicon. The first three constituents are definitely important to the metabolism of G. breve. The analysis of field water samples should indicate to what extent these factors may be growth-limiting or stimulating in nature.

Research at the Galveston Laboratory has progressed steadily in regard to defining the vitamin and trace element requirements of G. breve. Work on the nutrition of the organism has been considerably facilitated by the development of a virtually inorganic medium. This important step makes possible critical experiments to determine the importance of carbon and/or nitrogen-containing compounds to the growth and reproduction of this protist. We have also continued to investigate the effects of temperature, light, and salinity in terms of growth and survival of G. breve.

The screening of organic compounds has been continued in an effort to find a substance which will have practical value as a poison for the red tide dinoflagellate. During the year over 4,000 compounds have been tested for toxicity to G. breve cultures. A number of these seem to be even more toxic (per unit weight) than copper sulphate, the classical algaecide.



Pipetting aliquots from a field sample for G. breve counts.

Physiology of the Florida Red Tide Organism

David V. Aldrich

Effects of temperature and salinity on growth and survival of *Gymnodinium breve* cultures

The growth and survival of pure cultures of *G. breve* at various salinity levels in the laboratory have been found comparable to extended field study results. The organism seems unable to tolerate fresh or brackish water and thus probably subsists offshore between red tides.

Currently salinity is being considered in conjunction with two other ecological factors -- temperature and light -- in an effort to determine how these factors may interact to favor or inhibit the growth of *G. breve*.

We have established that the laboratory optimum growth range of temperature for *G. breve* lies between 15° and 30° C. In these experiments parent cultures were grown at 25° C. and provided inoculum for new cultures which were then exposed to the temperature to be tested. Since this method obviously may involve abrupt temperature changes, the results may suggest too restricted a tolerance range to provide information as to absolute limiting temperatures. Subsequent studies have been designed to evaluate the importance of (1) acclimation of established dense populations to gradual temperature changes and (2) growth temperature of parent cultures as a factor influencing growth and survival tolerance ranges of newly-inoculated cultures. Although equipment failure has prevented the completion of experiments of the first type, it is apparent that *G. breve* can tolerate slow temperature variations better than rapid ones. In a 6-week study of the parent growth-temperature influence, cultures inoculated with cells grown at 25° C. grew to peak population in 3 weeks at 25° and 19° C. Such cultures showed reduction of population at 15° C. after 6 weeks, while at 12° C. most tubes contained no living organisms after 10 days. Cultures inoculated with cells grown at a temperature of 19° C. grew slowly at 25° and 19° C., showed population loss at 15° C., but survived more than 3 weeks at 12° C. The difference in survival time at 12° C. suggests a strong parental influence, but the similarity of results at 15° C. does not seem to support this hypothesis. More work along the lines indicated above is in progress.

We have nearly completed an experiment in which three levels of temperature, salinity, and light have been mixed (in the 27 possible combinations) and tested for growth and survival of *G. breve*. The results should give some indication of how these three factors interact to determine environmental suitability for *G. breve*.

Carbon utilization by *G. breve* cultures The culture work of W. B. Wilson demonstrates *G. breve* to be capable of autotrophic nutrition. To what extent this organism is dependent on light as a direct source of energy must be determined if a complete picture of its nutrition is to be obtained. We have tried several experiments to determine the importance of various organic compounds as possible sources of energy for *G. breve*. Since the basic medium employed will not permit extended survival of this organism in darkness, the degree to

which an added substance serves as an energy source will be directly related to its ability to prolong survival in the absence of light. Seventeen carbohydrates (arabinose, ribose, xylose, rhamnose, fructose, sorbose, cellobiose, lactose, maltose, melibiose, sucrose, trehalose, melezitose, and raffinose) acetate, citrate, glycerine, urea, casein hydrolyzate, liver concentrate, bacterial extract, mold extract, soil extract, and mangrove extract have been tested, each being individually added to established cultures which were then kept in darkness. To date no compound or mixture has been found to support G. breve populations in the absence of light, even when the transition from light to darkness is made gradually. At this early stage of the work there is no evidence that this organism can derive energy directly from any source other than light.



Isolation of dinoflagellates for pure laboratory cultures.

Effects of light on growth and survival of G. breve Since light is definitely an important and possibly the sole energy source for G. breve, we are currently investigating the response of this dinoflagellate to various wave lengths and intensities of light.

Cultures exposed to artificial light intensities in excess of those used in our previous culture work (1,000, as compared to 500-600 foot-candles) showed no more rapid growth than previously obtained. This suggests that under our present culture conditions, light intensity is probably not a growth-limiting factor. At the 200 foot-candle level, however, no growth occurred and populations declined.

Growth studies in which newly-inoculated cultures were exposed to fluorescent, incandescent, indirect daylight, ultraviolet, and infrared radiation also indicated no definitely improved growth. Ultraviolet-treated cultures were so adversely affected that in 60 percent of replicate tubes no living cell could be found after 10 days.

Individual mass cultures exposed to filtered light of various wave lengths but similar intensity, usually showed highest cell concentrations in blue or green light. This result suggests the action of a tropism.

A similar but more marked response is evoked by polarized light, which seems to concentrate many more organisms than does non-polarized light of the same intensity. A growth study using these two types of light is in progress, and cell counts to date suggest that polarized light may stimulate more rapid growth than ordinary light.

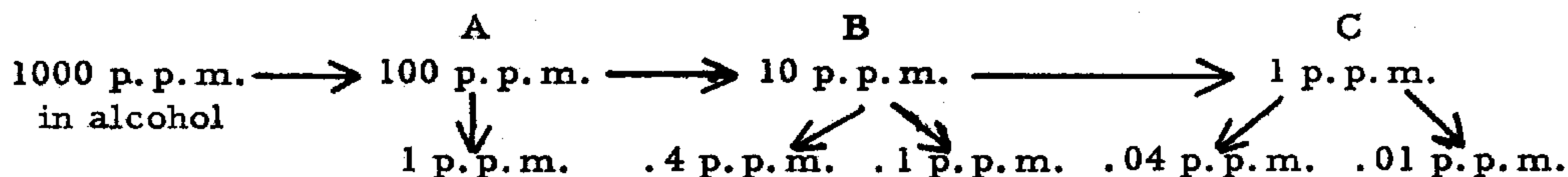
Chemical Control Experiments

Kenneth T. Marvin

The systematic screening of organic compounds to determine their relative effectiveness as Gymnodinium breve toxicants was started in March 1959. This constituted the first phase of a program to find an effective chemical means of controlling the extensive blooming, and thus the accompanying widespread damage of the red tide organism.

Control attempts have been made by dusting affected areas with copper sulphate. However, due to the gradual precipitation of copper in sea water, success by this means has been limited to localized areas and short periods of time. The chemical sought must be toxic to G. breve at very low concentrations and must not have the precipitating characteristics of copper. Also, it must be selective to an extent that it will not adversely affect commercially important organisms.

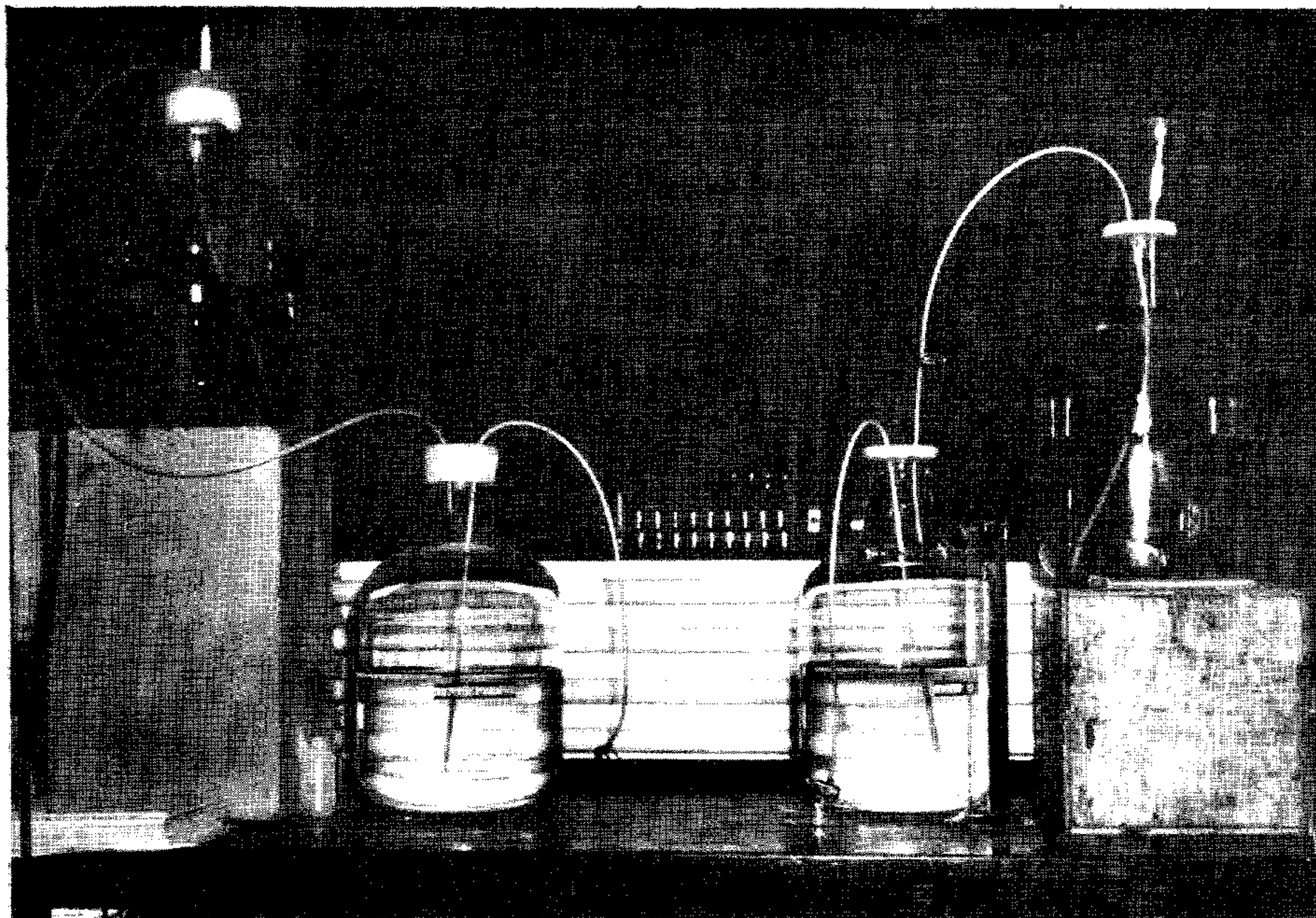
Most of the chemicals tested are soluble in alcohol but not in water. Therefore, they are placed, first in an alcoholic solution. From this, through a series of distilled water dilutions, the desired concentrations in G. breve culture are obtained. The steps involved can best be demonstrated as follows:



The intermediate solutions, A, B, and C, are made with distilled water. Portions of these are added to G. breve cultures to give the concentrations shown. After 24 hours an estimate is made of the changes in population (to the nearest 25%) as compared to control cultures. All estimates are based on 10 ml. of culture in 25 ml. soft glass culture tubes.

Several sources of error involved in this phase of the work could not be economically eliminated during a large-scale control program. Therefore, no attempt has been made to eliminate them in the laboratory. Probably the most serious of these is that many of the compounds tested precipitate or form an emulsion when converting from an alcoholic to a water solution. This can result in non-homogeneous intermediate solutions (A, B, and C) which in turn decreases the reliability of the final dilution figure. Some of the compounds tested were not completely soluble in alcohol at the initial concentration of 1,000 p.p.m. (0.1%). Evidence of these conditions are noted on the data card for the compound tested, but no attempt is made to correct for the dilution error. Several conditions exist that could lead to the misinterpretation of results. One is the possibility that some of the chemicals react with alcohol to give either more or less toxic products. For this reason the techniques and procedures used in the laboratory should be duplicated in any subsequent large-scale control work as closely as possible. Another is the fact

that many of the compounds being screened had been stored for several years at room temperature. The more unstable ones have, undoubtedly, undergone chemical changes that have varied their toxicity to G. breve as compared to the freshly prepared material.



Mass cultures of G. breve for toxicity screening of organic compounds.

Volumetric and weighing errors, contaminated glassware, and also variation in the condition of the test organism affect the apparent levels of toxicity. Results of 16 tests of copper sulphate shown were obtained on separate days and represent freshly prepared solutions, glassware, etc.

Mortality in 16 replicate experiments at 6 concentrations of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

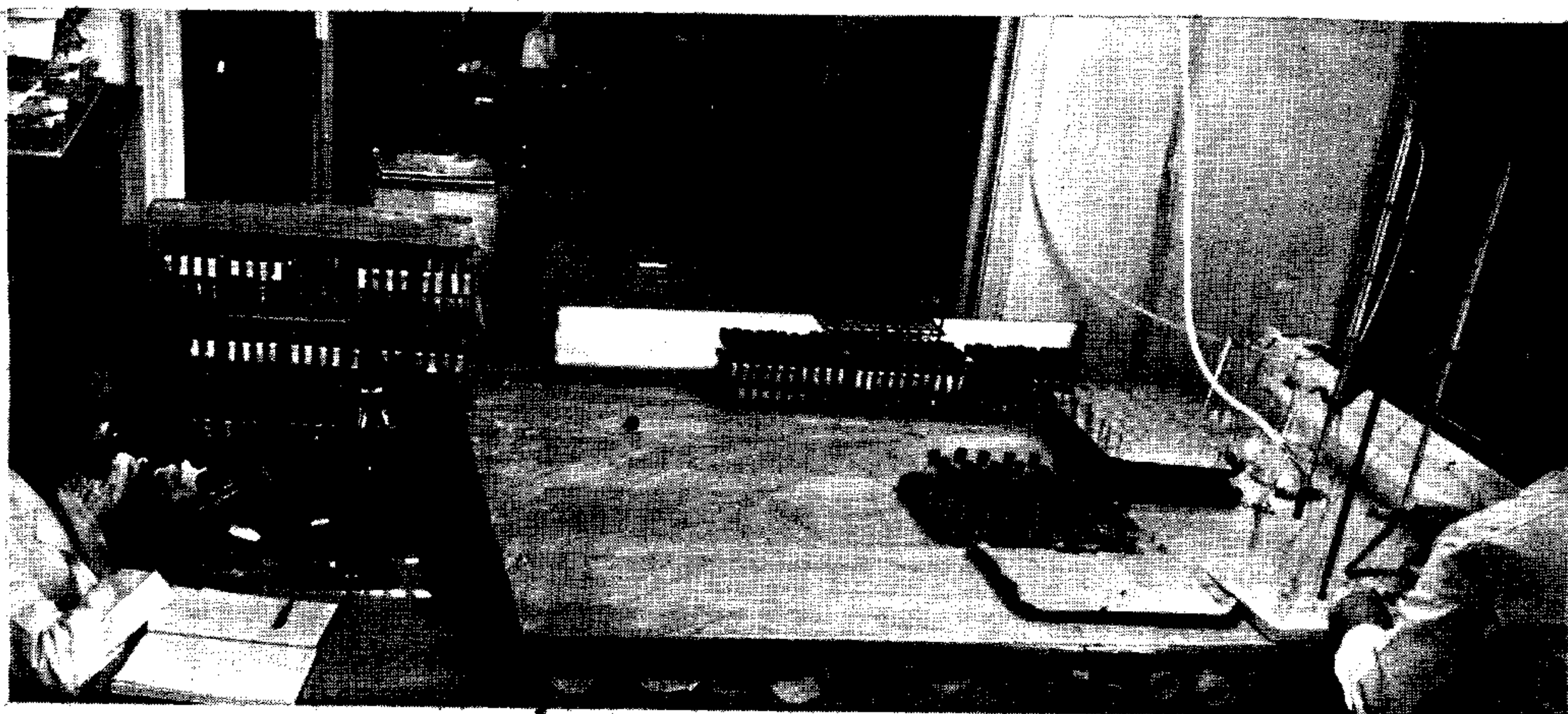
Concentration			Frequency at each percent				
p. p. m.		$\mu\text{g. at. Cu/l.}$					
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	Cu		100	75	50	25	0
.10	.025	.39	0	1	3	2	10
.12	.030	.47	7	4	1	1	3
.14	.035	.55	11	2	1	2	0
.16	.040	.63	14	0	2	0	0
.18	.045	.70	15	1	0	0	0
.20	.050	.78	15	1	0	0	0

To date 4,000 compounds have been tested. A summation of results as to the major groups involved and also the toxicity range of the chemicals tested is shown in the table.

Results of screening 4,000 compounds

Compounds containing:	Total tested	Total toxic at:				
		.01 p.p.m.	.04 p.p.m.	.10 p.p.m.	.40 p.p.m.	1.0 p.p.m.
Amines	856	19	83	117	242	328
Nitro	496	1	8	27	79	117
Phenol	236	8	29	49	95	127
Mercury	28	6	10	12	13	13
Sulfur	592	9	31	61	169	235
Amides	228	3	4	11	35	42
Cyanides	202	1	13	19	59	93
Copper	32	0	1	2	16	27
Quinones	13	0	5	7	7	10

The present phase of the program will continue at least until the completion of our sea-water system. The holding tanks that will be included will allow us to keep an adequate number of test organisms to be used in the second phase of the program, which will consist of determining the effects of toxic compounds on commercially important organisms.



Screening of organic compounds for toxicity to G. breve.

Field Chemistry

Billie Z. May

The chemistry laboratory has been routinely determining the following chemical parameters for water samples from Tampa Bay and vicinity: copper, salinity, inorganic phosphate, total phosphate, and nitrate-nitrite. The analysis of copper was discontinued in December 1959 and analysis for inorganic phosphate in April 1960. Five new analyses have been undertaken, four by our laboratory and one tentatively scheduled to be performed on contract with the University of Tampa. The four new analyses are calcium, silicon, alkalinity, and ammonia. Total nitrogen is to be undertaken by the University of Tampa. At present the University chemistry department is refining the procedure to be used in such an analysis. Experimental results indicate that we should be able to dispatch our first (April) samples to them for analysis within a short period. If preliminary results of those analyses are practical and promising, the University of Tampa will continue to perform them until we are able to purchase the necessary specialized equipment to enable our laboratory to perform micro-distillation.

The total number of determinations for the period of this report (these include regular standards run with the unknowns) is: copper, 2,677; salinity, 1,965; inorganic phosphate, 3,632; total phosphate, 3,595; nitrate-nitrite, 3,632; calcium, silicon, alkalinity, 97 determinations each; and ammonia, 14 determinations. Sampling plans call for the inclusion of ammonia from surface samples corresponding to sampling for total nitrogen, and as a result 14 of each are taken monthly. The grand total of determinations above is 15,344.

Sampling for the parameters above was carried out as follows: three depths at each station were sampled except for subarea 6 (the four offshore stations), where four depths were sampled, top, first intermediate, second intermediate, and bottom. Casts were made with a modified Van Dorn water sampler described by Finucane and May. In this sampler water contacts only inert surfaces, such as plastic and rubber, avoiding metallic contamination.

Water samples for biological examination were drawn off through a polyethylene spigot, dispensed into 2-liter Erlenmeyer flasks, and rubber capped. Samples for copper were dispensed into 250-milliliter glass-stoppered, pyrex reagent bottles. For salinity, water was dispensed into 4-ounce prescription bottles capped with plastic. Inorganic phosphate, total phosphate, nitrate-nitrite, ammonia, and total nitrogen sea-water samples were dispensed into 25 x 200 milliliter pyrex culture vials and capped with poly-seal closures. Inorganic phosphate, nitrate-nitrite, ammonia, and total nitrogen vials were immediately placed in a -20° C. deep freeze. Water samples for calcium were taken in 250-milliliter reagent bottles. Samples for alkalinity were taken in 8-ounce flint-glass bottles, capped with poly-seal closures. Silicon

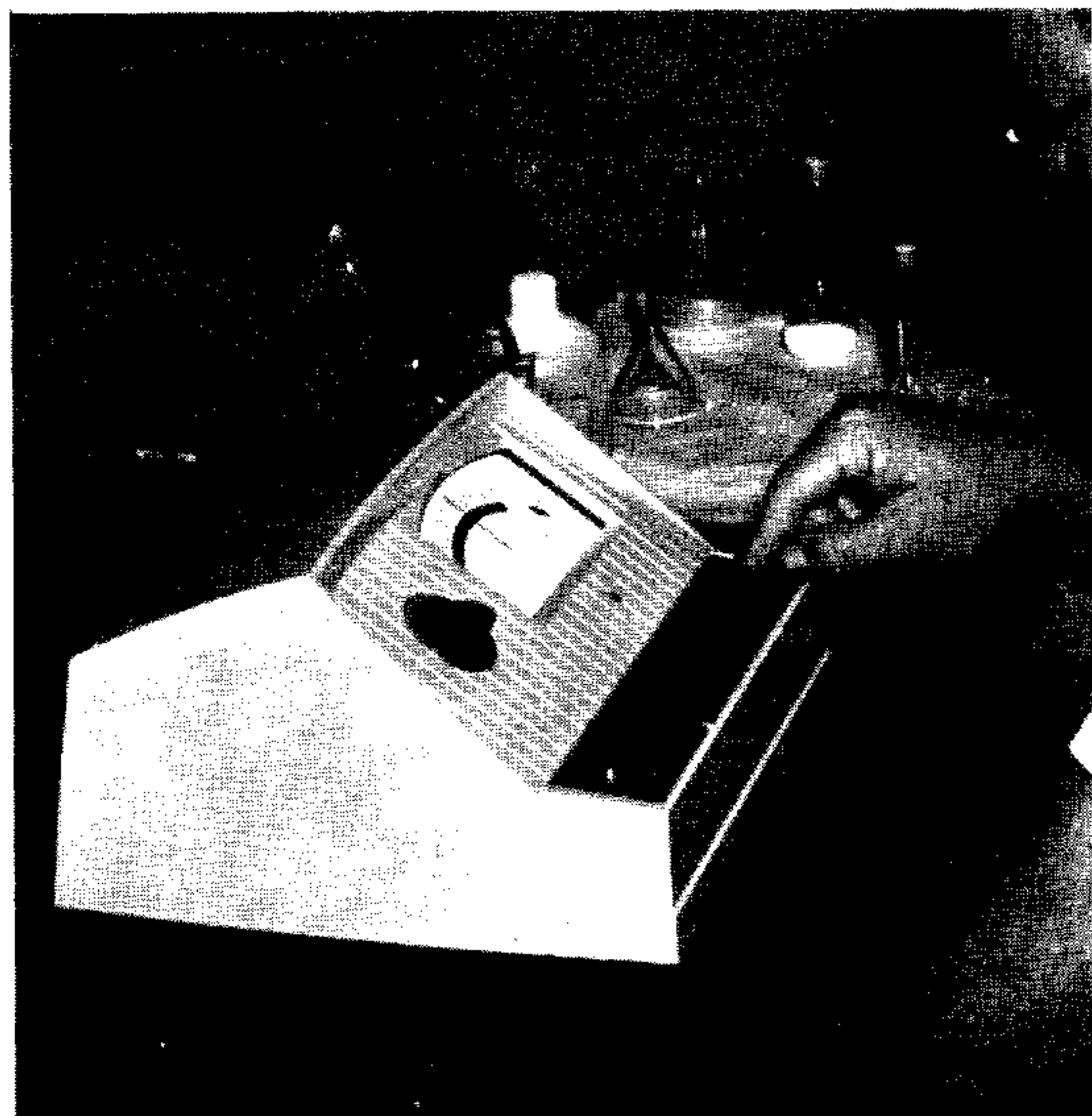
samples were dispensed into 4-ounce polyethylene bottles with polyethylene caps. All the glassware described above is previously chemically cleaned in the laboratory. Every effort is made by the laboratory to perform analysis of the samples as soon as possible to alleviate errors due to changing composition upon lengthy storage.

The copper content of sea water is measured in our laboratory colorimetrically using the method of Hoste, Eeckhout, and Gillis. The chlorinity titration is carried out according to the classic Mohr silver nitrate titration. The corrected chlorinity thus found is used to determine the salinity from the Hydrographical Tables (Knudsen). Both inorganic phosphate and total phosphate analyses are determined according to the method of Harvey. The method of Zwicker and Robinson as modified by Marvin for the estimation of the nitrate-nitrite content of sea water is used by our laboratory.

Calcium determinations take considerable time if they are performed according to the gravimetric method. The biologist must have the results quickly, and a great strictness is not absolutely necessary. One of the quickest methods is the direct titration of sea water with the aid of EDTA (disodium ethylenediaminetetra-acetate). This is the method we utilize. The concentration of EDTA is such that titration in milliliters is equivalent to mg.-atoms/l. of calcium.

Our laboratory measures silicon according to the method of G. A. J. Armstrong. Alkalinity is measured according to the method of Thompson and Anderson. The pH of a sample treated with standardized HCl is measured and the alkalinity calculated from suitable equations. The method of Wirth and Robinson is followed for the estimation of ammonia.

Determining pH for alkalinity measurement.



Hydrology of Tampa Bay and Adjacent Waters

Alexander Dragovich

In ecological studies of phytoplankton, simultaneous hydrological investigations are extremely important since they provide data for comparison of the incidence of phytoplankton and physico-chemical characteristics of water masses. Hydrological characteristics of Tampa Bay and adjacent neritic waters are determined to study their relationship with the temporal and spatial distribution of Gymnodinium breve, the Florida red tide organism.

Up to January 1, 1960, the entire area was sampled regardless of the tidal stage; thereafter, all stations in Tampa Bay and up to $3\frac{1}{2}$ miles offshore were sampled on high high tide \pm 1 hour. This adjustment permits better evaluation of seasonal changes in parameters.

Temperatures From May 1959 through May 1960, 1,235 water temperature determinations were made in Tampa Bay and adjacent neritic waters. The minimum water temperature (11.7° C.) was observed in January 1960 at station 5 in lower Tampa Bay, and the maximum (31.7° C.) was recorded in September 1959 at station 7, also in lower Tampa Bay. From June 1959 through February 1960 the vertical temperature variations in Tampa Bay and in neritic waters up to 40 miles offshore were slight. The exception to this was a sharp negative gradient recorded during September at 40 miles offshore. A similar condition was observed in the same area during October 1958. The temperature of these cool bottom waters ranged from 23.2° C. to 24.5° C. while salinities varied from 35.66‰ to 35.81‰. G. breve was absent in the samples collected from these waters. In March, April, and May 1960, during the period of vernal warming, a negative vertical gradient was formed, especially well pronounced in 20-40 miles offshore waters.

Comparison of the water temperatures with incidence of G. breve indicates that a relation to temperature may exist, especially during the cold periods. During the winter the temperature of water 20-40 miles offshore was higher than that of inshore waters. This may be important in the survival of G. breve offshore. During February and March 1960 these temperatures were 4° - 5° C. colder than during the corresponding period of the previous year.

Salinity Since sampling on high high tide \pm 1 hour, the salinity data in Tampa Bay have varied inversely with rainfall. Results continue to show a horizontal salinity gradient with maximum values in offshore areas and minimum in upper Tampa Bay. The salinity maximum (36.40‰) was recorded at 40 miles offshore and at 80 feet depth while the minimum (12.70‰) was in the surface water of upper Tampa Bay in March during the period of maximum fresh-water discharges for 1960.

Rainfall (June 1959-April 1960)

Precipitation in inches. Figures in parenthesis represent normal values.

	June	July	Aug.	Sep.	Oct.	Nov.
Tampa	9.13 (7.77)	7.29 (8.11)	10.44 (8.06)	8.49 (6.45)	6.26 (3.14)	1.02 (1.04)
St. Petersburg	10.60 (6.13)	13.12 (8.94)	9.54 (9.16)	8.67 (8.52)	8.59 (3.49)	1.26 (1.78)
	Dec.	Jan.	Feb.	Mar.	Apr.	
Tampa	2.25 (1.96)	1.32 (1.99)	3.70 (2.50)	11.00 (3.12)	1.66 (2.51)	
St. Petersburg	2.95 (2.06)	1.48 (2.44)	4.12 (2.94)	7.75 (3.18)	6.16 (2.86)	

There were two outstanding features in the distribution of salinities in Tampa Bay and adjacent neritic waters. First, Tampa Bay salinities are affected by the massive fluvial discharge during the rainy season. The incidence of G. breve in Tampa Bay during the onset of the rainy season varies considerably from year to year. For example, during March 1959, the month of record rainfall (12.64 and 11.33 inches), G. breve was absent in the samples from Tampa Bay. In March 1960, during similar rainfall conditions (11.00 and 7.75 inches), concentrations of G. breve varied from 0 to 80,000/l. The fact that during the 6 months preceding March 1959 red tide blooms were absent, while during the same 6 months in 1960 there were blooms of G. breve, suggests that the size of a G. breve population may be important for its survival in Tampa Bay during the onset of a rainy season when a drastic reduction of salinity occurs.

The second outstanding feature is the salinity difference between surface layers from 30 and 40 miles offshore in June and from 20 and 40 miles in July and August. The data suggest that the existence of surface waters with slightly reduced salinity at 30 and 40 miles offshore is possible. A reduction of salinity in this area may be indicative of conditions favorable to G. breve. With the exception of April, from September through May the surface salinities in the offshore waters were higher 40 miles offshore than at 30 miles offshore. In April the reverse situation occurred, the values being 35.14‰ and 35.05‰.

The vertical salinity structure in Tampa Bay and adjacent neritic waters showed a regular response to the fresh-water discharges in the surface waters, and the resulting haline stratification was evident throughout Tampa Bay. This effect was less obvious in the neritic waters.

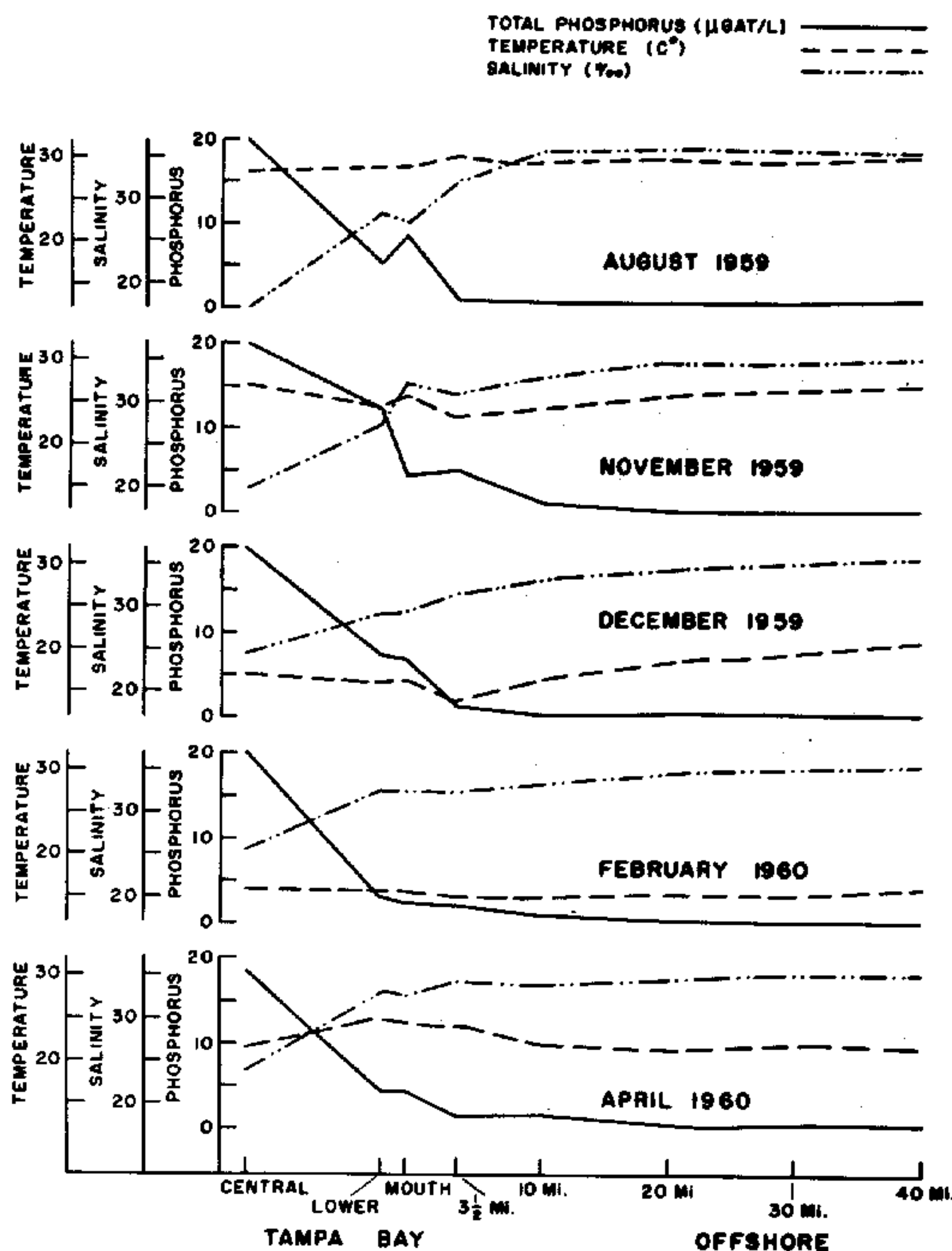
Total and inorganic phosphorus

Because phosphorus is an important nutrient for phytoplankton, this element has been the subject of field studies. A prominent feature of both the total and inorganic phosphorus is the horizontal distributional pattern which shows a maximum zone in central Tampa Bay and rapidly diminishing concentrations seaward. The source of the high concentrations in Tampa Bay is river waters which flow over surface phosphate-bearing formations. Among four rivers flowing into Tampa Bay the greatest contributor of phosphorus is the Alafia River.

Vertical distribution of phosphorus in lower Tampa Bay and up to 10 miles offshore shows peaks at the surface, suggesting that the source of phosphorus may have been discharge waters. At 20 miles offshore this enrichment was noticed only on occasions, while at 30 to 40 miles offshore there was only slight evidence of it.

Although the annual amount of total and inorganic phosphorus entering Tampa Bay varies, a general seasonal pattern exists, in which the greatest proportion of phosphorus is introduced at the beginning of the rainy season. Most of the phosphorus in Tampa Bay is in inorganic form (61-94 percent). The proportion of organic phosphorus increases seaward from the mouth of Tampa Bay but rarely exceeds that of inorganic phosphorus. An exception occurred during the outbreak of red tide in September, October, and November, 1959 when organic phosphorus represented as much as 78 percent of total phosphorus.

The phosphorus data show no signs of the seasonal buildups observed in northern latitudes.



Means for certain months of temperature, salinity, and total phosphorus for Tampa Bay and adjacent neritic waters.

Nitrate-nitrite nitrogen The concentrations of nitrate-nitrite nitrogen in 1,080 samples varied from 0.0 to 1.8 $\mu\text{g. at. /l.}$ In 87.7 percent of observations the concentration of nitrate-nitrite nitrogen ranged from 0.1 to 0.5 $\mu\text{g. at. /l.}$; in 12.9 percent it was above 0.6, while in 4.4 percent there were no measurable quantities. This indicates that Tampa Bay and adjacent neritic waters are poor in nitrate and nitrite compared to other marine areas such as the Gulf of Maine, the English Channel, or the Arabian Sea. The seasonal distribution of nitrate-nitrites seems to be very irregular. No relationship was observed between the incidence of G. breve and nitrate-nitrites.

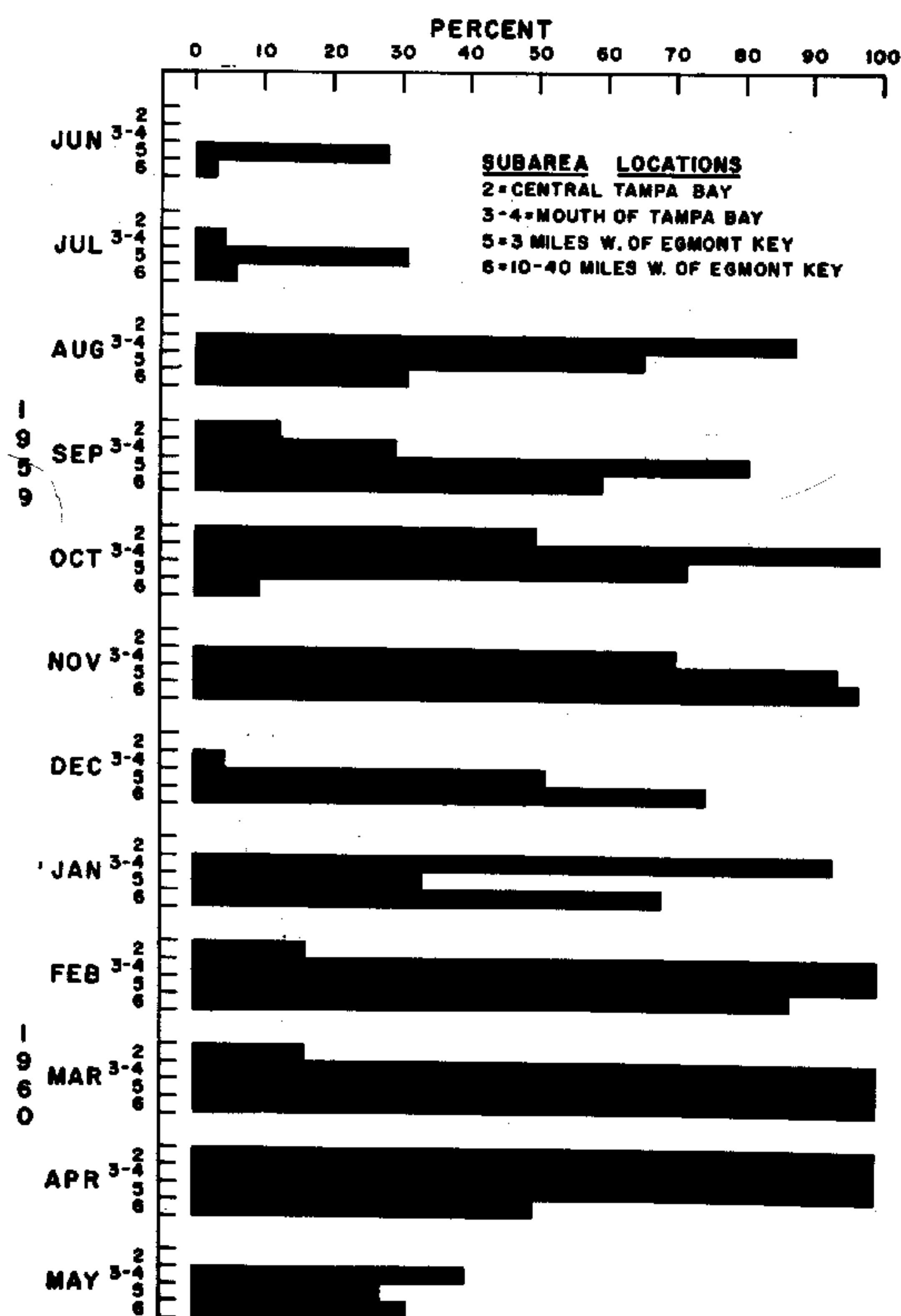
In view of the low level of nitrates and nitrites encountered and the accepted importance of the nitrogen cycle in phytoplankton physiology, we have collected surface samples for the determination of ammonia and total nitrogen since April.

Sampling and determinations of alkalinity, calcium, and silicon were also started in April. At present we have insufficient data to delineate the seasonal or areal patterns of these parameters.

Field Ecology Relating to Red Tide

John H. Finucane

Geographical distribution As a continuation of our sampling program on the ecology of Gymnodinium breve within a major drainage area, stations were occupied monthly in Tampa Bay and adjacent neritic waters. Since June 1959 a total of 1,223 water samples were examined for the presence of G. breve and associated phytoplankton. Of these samples, 46 percent contained G. breve.



Percentage of samples
containing G. breve.

The 1959 red tide outbreak started during the last part of September and continued through November. The initial pattern of distribution was similar to the 1957 outbreak with blooms of G. breve first occurring outside the islands. The first fish kill was reported September 29, offshore from St. Petersburg Beach. The greatest observed numbers of G. breve (480,000-1,330,000 per liter) were found in the neritic waters 3-10 miles west of Egmont Key, September 30. By October there was a rapid decline in both numbers and incidence of G. breve, 10-40 miles west of Egmont Key. This was particularly noticeable at stations 10 miles offshore where the numbers dropped from 1,120,000 per liter in September to less than 100 per liter during October. The coastal waters north of Egmont Key to Clear water had a high count of only 33,000 per liter as compared to 540,000 per liter at the stations south of Egmont Key to Venice the same month. The last recorded fish kill during this outbreak occurred October 22, 1959, 3 miles west of Egmont Key.

The incidence of G. breve decreased in Tampa Bay and the near-shore waters during November, but blooms of this organism to 400,000 per liter still occurred 10 miles west of Egmont Key. Following the advent of weather fronts accompanied by lower water temperatures and turbulent sea conditions, G. breve incidence and numbers declined during December 1959 and January 1960.

From February to April 1960 G. breve increased again in numbers and distribution. In March, 35 miles west of Egmont Key, a bloom of 6,320,000 per liter was observed. Scattered dead fish extended 15-35 miles offshore. No further fish kills were reported in April and May. The highest population encountered at that time was 21,000 per liter 10 miles west of Egmont Key.

Vertical distribution The majority of water samples still showed the greatest numbers of G. breve on or near the surface in the relatively stable offshore waters. In shallower neritic and estuarine waters where mixing of the entire water column may occur, surface and subsurface counts were similar. This was especially noticeable from February through April 1960. During a 24-hour vertical migration study of G. breve, conducted in an area 3 miles west of Egmont Key, October 6 and 7, 1959, no definite diurnal pattern was shown at a depth of 26 feet. Unstable weather during part of the sampling period may have influenced results.

The neritic nature of G. breve was indicated by its presence to depths of 123 feet in numbers ranging from 7,000-16,100 per liter, 40 miles west of Egmont Key, November 1959 and March 1960.

Seasonal occurrence Organisms were present in the nearshore and offshore waters throughout the year during non-bloom periods, the greatest incidence and numbers occurring from September to December 1959 and from February through March 1960. G. breve was completely absent from the middle of Tampa Bay except during the blooms of September-October 1959 and February-March 1960. This suggests that G. breve is primarily a neritic organism found in estuarine waters only when special conditions exist.

Observations on salinity, temperature, and the distribution of G. breve Organisms were generally present in lower than normal salinities, ranging from approximately 30-35‰ during blooms. Waters having values less than 24‰ did not contain blooms of G. breve in Tampa Bay. While salinity may have served as a barrier for G. breve in estuarine waters, it does not normally seem to be a limiting factor in neritic waters.

Water temperatures above 22°C. seem to be favorable for blooms of G. breve with the optimum around 26°-28°C. However, during February and March 1960, dense populations of G. breve developed at temperatures between 15°-18°C. Since G. breve has been observed in waters as cold as 9°C., low water temperatures normally may not be an absolute limiting factor for the existence of this organism. Temperatures below 14°C. and above 30°C. may inhibit blooms.

Associated phytoplankton Diatoms were abundant in the spring and summer, and both diatoms and dinoflagellates during the fall and winter in neritic and estuarine waters. G. breve was one of the dominant dinoflagellates during 1959 and 1960.

Blooms of Prorocentrum micans and Ceratium furca occurred during November and December 1959 in Tampa Bay. For the first time during this investigation, blooms of Gymnodinium splendens were present March 29, 1960, in upper and middle Tampa Bay. These blooms followed periods of abnormally high rainfall and phosphate values.

Skujaella erythraeum continued to be the dominant blue-green alga in the surface waters from Tampa Bay to 40 miles west of Egmont Key during the summer and fall of 1959.

Numbers of G. breve per milliliter 10-40 miles west of Egmont Key
(June 1959-June 1960)

Miles out	Depth ^{1/}	1959							1960				
		Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
10	1 S.	P ^{2/}	0	0	320	0	400	20.0	P	48	180	21.0	P
	2	0	0	0	1120	0	160	0.9	0	150	26	0.4	0
	3	0	0	0	40	P	40	P	P	20	22	0	0
	4 (48)	0	P	0	12	0	30	P	P	25	16	0	0
20	1 S.	0	0	0.1	10	0	1.6	2.8	0	175	220	3.2	P
	2	0	0	P	26	0	2.4	1.9	P	68	5	P	P
	3	0	0	P	12	0	0.4	1.5	P	10	4	0	0
	4 (79)	0	0	P	6	0	2.0	1.5	P	0.8	8	P	0
30	1 S.	0	0	P	P	0	0.6	P	1	114	800	0.6	P
	2	0	0	P	0	0	0.6	0.1	P	P	8	0	0
	3	0	0	P	0	0	0.1	0.1	P	1.2	0.8	0	0
	4 (102)	0	0	0	0	0	0	0.1	0	2.6	20	0	0
35	1 S.										6320		
	1 S.										1230		
40	1 S.	0	0	0	0	0	13	0	P	P	300	2.4	P
	2	0	0	0	0	0	8	0	0	0	70	P	0
	3	0	0	0	0	0	9	0	0	0	20	0	0
	4 (123)	0	0	0	0	0	7	0	P	0	16	0	0

^{1/} S equals surface; number in parenthesis equals bottom depth in feet.

^{2/} P equals less than 0.1 per milliliter.

EFFECTS OF ENGINEERING PROJECTS ON ESTUARIES

Ronald C. Naab

Value of the estuarine areas as nursery grounds for many major marine species is well established. Biological effects of water development practices will likely be extensive. Unfortunately, our present state of knowledge does not permit an accurate prediction of the effects on marine fishery resources resulting from changes in the natural conditions of the estuaries.

Though they cannot be evaluated with assurance, it may be appropriate to mention several foreseeable changes to be wrought by water development projects and presage estuarine effects. The most obvious alteration of present conditions will be reduction of streamflow through greater consumptive use and increased evaporation rates owing to the exposed surface area of reservoirs. A reduced influx of freshwater may alter the suitability of estuarine areas by increasing salinities; by varying salinity, circulation, and interchange patterns; by reducing inflow of land-derived nutrient materials needed for primary productivity; by lessening silt load and deposition; by diminishing turbidity; and by draining of ambient marsh area through lowering of river levels. As the population increases and industrial and agricultural interests expand, it is logical, in view of present facilities, to anticipate an increase in pollutants entering the estuaries with the remaining runoffs and waste waters. Influence of the inshore waters on the hydrography and food cycles of offshore waters is not clearly defined but presents yet another factor to be considered in assessing the effects of drastic modification of river systems and their associated estuaries.

The Trinity River of Texas affords an excellent example of the many extensive water development programs contemplated for the major watersheds entering the Gulf of Mexico. From its headwaters north of the Dallas-Fort Worth area in northeast Texas, the Trinity River flows southeasterly over 300 miles terminating in Trinity Bay, a segment of the Galveston Bay system. The Trinity River, the largest tributary of the Galveston Bay estuary, is one of the major factors determining hydrologic conditions in the Bay.

Traversing the most densely populated areas of the state, the Trinity's waters are presently subjected to considerable exploitation for municipal, agricultural, and industrial interests. Impoundments near the headwaters supply the major share of water for the cities of Dallas and Fort Worth. Smaller cities, combined with agricultural and industrial concerns, place a further drain on the flows throughout its lower reaches, and Houston, the metropolis of Texas, does plan to acquire Trinity waters in the near future to satisfy its rising fresh-water needs.

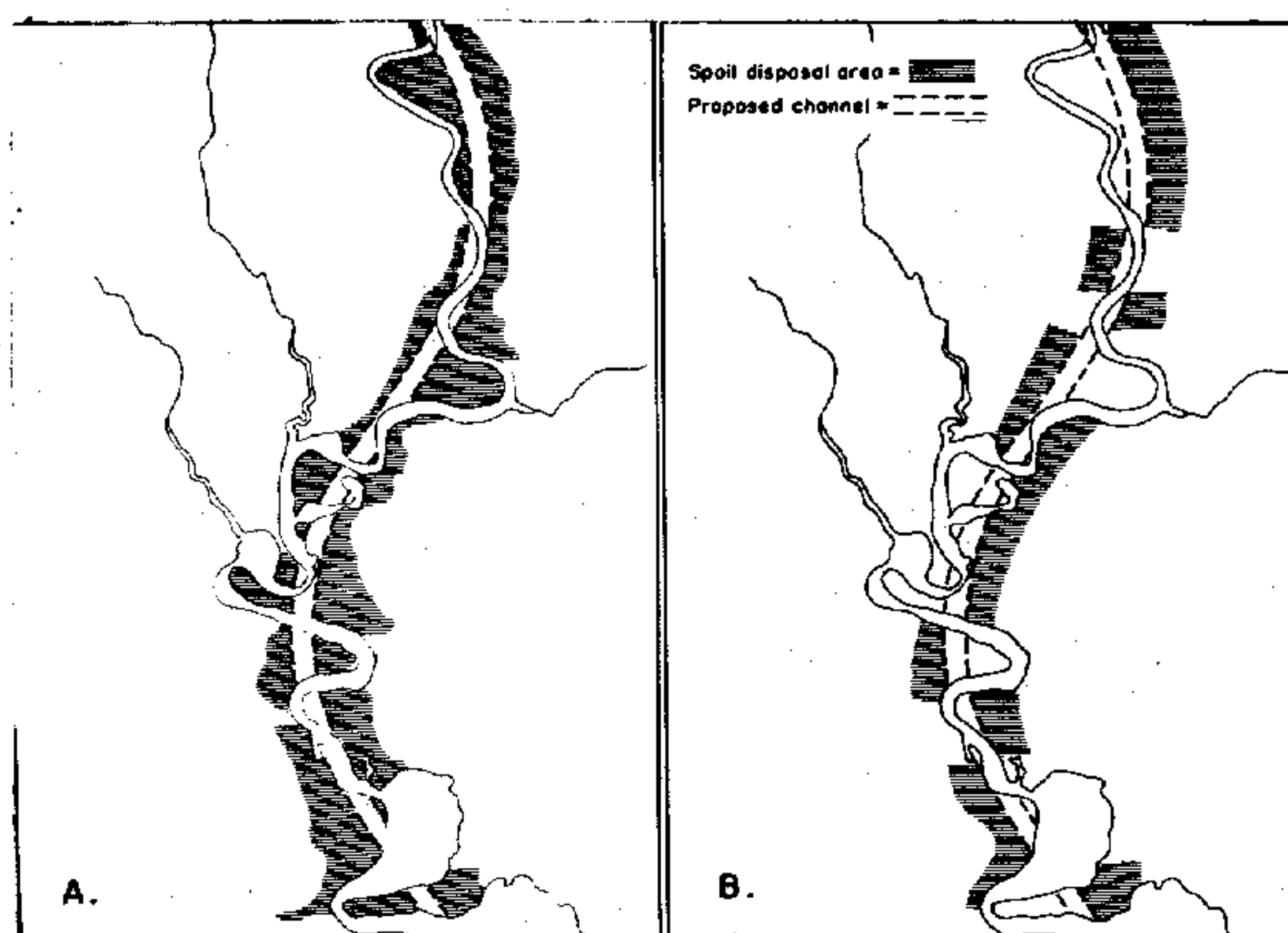
In 1955 the Trinity River Authority was created to guide water development throughout the Trinity River drainage. The TRA devised a master plan based on the premise that all of the runoff of the Trinity River and its

tributaries that can be regulated economically will be required in future years for development in the watershed. This master plan proposes construction of 4 large water supply reservoirs on the main stem of the river and 13 smaller reservoirs on tributary streams. At present there are about 14 relatively small reservoirs on the watershed located mainly in the Dallas-Fort Worth region. The Livingston Dam to be constructed by the City of Houston is one of the main stem structures outlined in the TRA plan. This reservoir will eventually be coupled with a smaller complementary impoundment near the mouth of the Trinity River serving essentially as a salt-water barrier.

Federal agencies, as the Bureau of Reclamation and U. S. Corps of Engineers, are considering further utilization of Trinity River stream flows. The United States Study Commission has as its purpose the formulation of an enduring water supply and control program for the entire state of Texas. Large variations in climate prevail in the state, and naturally the available fresh-water supply is most critical in the semi-arid to arid southern and western regions. One suggested means of alleviating this condition is diversion of a portion of the "surplus" runoffs from the major rivers to the semi-arid lands. The Trinity is a major river of the state and is included in those proposed for flow diversion. Surplus runoff is apparently considered as all non-exploited flows entering the estuarine systems.

A further reflection of the expanding population and economy is illustrated by the increasing numbers of navigation and general construction projects which also modify the Gulf of Mexico estuaries and their suitability as marine habitat. Addition, realignment, and maintenance of navigation channels associated with the Intracoastal Waterway are projects frequently submitted for evaluation of effects on marine fishes. General construction projects is a term encompassing such items as small fills, mineral drilling facilities, pipeline crossings, wharf construction, and others generally having minimal effects on marine fishery resources.

Channelization dredging of a typical Gulf of Mexico bayou to illustrate the placement of spoil as usually proposed (A) and to maintain marsh habitat (B).



Major alteration of water circulation and interchange through segmentation and "canalization" of the estuaries and tributaries by channels and adjoining spoil banks is considered the main danger of navigation projects, aside from the actual physical loss of habitat. Proposed channel alignment and spoil placement with resultant canalization of a typical bayou estuary are shown in Section A of the accompanying figure. To minimize loss of marsh areas and alleviate sloughing of spoil into the original channel and tributaries, alteration of the spoil disposal areas could be made similar to segment B of the figure.

The individual project in the general construction category is usually not sufficiently extensive to be considered detrimental. However, through sheer numbers they may produce serious cumulative encroachment upon available and apparently adequate estuarine areas.

Accurate evaluation of the effect of engineering projects upon marine stocks is seldom possible with present insufficient knowledge by areas of species utilization and hydrological effects. Lacking accurate evaluation data, we often can only recommend plan changes, where practicable, that will minimize alteration of present conditions.

Biological and Hydrological Studies for the Corps of Engineers
Mississippi River-Gulf Outlet Project, Louisiana

Dr. Kenneth M. Rae, Texas A & M Research Foundation
(Contract No. 14-17-008-119)

An earlier report (Texas A & M Research Foundation Report 59-21T, September 1959) summarized the hydrological and meteorological data obtained prior to June 30, 1959. In September 1959, a new contract was entered, under which the scope of the program was broadened to include biological studies in the project area.

The immediate objective of the biological investigations was a preliminary analysis of the major biological components and information on the distribution of the fauna in that region which might be influenced by the engineering project. It can be assumed from the hydrological observations so far made that any environmental changes introduced by the engineering project will be towards the fresh-water complex of Lake Borgne or towards the more saline complex associated with Breton Sound. By comparing the fauna and the relative abundance and growth rates of selected species in saltier and fresher parts of the system some forecast of the effect of such changes should become possible.

The project area which comprises a complicated system of lakes, ponds, and bayous was, therefore, divided into three major sub-areas, each designed to be as nearly self-contained hydrologically as possible (see figure). Salinity was a major determining factor in this division. Sub-area 1 (Bayou Dupre Complex) is characterized by a low salinity range (1.0-6.5‰) and is taken as being representative of the fresh water environment stemming from Lake Borgne. Sub-area 3 (Lake Eloi-Lake Athanasio Complex) is located at the southeast of the project area and is typical of the higher salinity conditions (9.2-18.0‰) as it is under the influence of the waters of Breton Sound. Sub-area 2 (Bayou St. Malo Complex) has a salinity intermediate between the other two (2.3-9.8‰).

Four or five stations were located in each of the three sub-areas, the object being to sample at each station at least once every 10 days.

Various types of gear were employed to obtain representative samples of the population. A 12-foot otter trawl of standard design with a cod-end mesh of $1\frac{1}{4}$ inches was towed behind a small shrimp boat. Standard hauls of 10-minutes duration were made at each station. A small 3-foot shrimp try-net ($1/8$ -inch mesh) was also used to sample the smaller animals. This net was hauled for 5 minutes at each station. A rectangular dredge (mouth opening 16 x 15 inches covered with $\frac{1}{4}$ -inch wire screen) was used to collect the bottom animals such as oysters, clams, and other mollusks. The dredge was dragged behind the boat for 3 minutes at each station. Zooplankton samples were obtained by towing a $\frac{1}{2}$ -m. nylon plankton net (No. 6 mesh) behind the boat for 5 minutes.

Some experimental sampling was done with a small mid-water trawl to collect the members of the macroplankton that were not captured by the ordinary slow-speed plankton net.

Unfortunately, the number of animals taken by the sampling gear was lower than expected. Considerable pooling of data from the various stations is necessary for statistical treatment of the data. However, as the dredging of the channel was proceeding rapidly, it seemed wiser to retain a standard method of collection - and so obtain inter-comparable results - than to modify the collecting gear. Again due to limitations in time, some selection of animals for more intensive study was necessary. Emphasis has been placed on the fish, shrimp, crab, and oyster populations. Special attention is also being given to the distribution and the growth rates of selected species which are common to all three sub-areas.

Altogether 22 boat trips were made between October 1959 and May 1960. A total of 279 stations were occupied during this period. At these stations the following numbers of hauls were made:

<u>Otter Trawl</u>	<u>Try Net</u>	<u>Dredge</u>	<u>Plankton Net</u>
261	247	256	269

Forty-nine species of bony fish were collected in the project area. These species represent 45 genera and 31 families. The total number of fish collected was 6,473. Of these fish 43 percent were taken in sub-area 1; 23 percent were taken in sub-area 2; 34 percent were taken in sub-area 3. Of the 49 species collected, 3 were found only in sub-area 1; these were Ictalurus furcatus, Alosa chrysochloris, and Pogonias cromis. Seven species were found only in sub-area 2; these were Syngnathus sp., Lucania parva, Cyprinodon variegatus, Microgobius gulosus, Mollienesis latipinna, Lepisosteus productus, and Menidia sp. The 10 species found only in sub-area 3 were Spheroides sp., Synodon foetens, Polydactylus octonemus, Bagre marina, Caranx latus, Gobiesox strumosus, Chaetodipterus faber, Etropus crossotus, Astroscopus y-graecum, and Dorosoma petenense.

Seventeen species of fish were common to all three sub-areas; these were Gobiosoma bosci, Cynoscion arenarius, Galeichthys felis, Micropogon undulatus, Trinectes maculatus, Leiostomus xanthurus, Bairdiella chrysura, Anchoa mitchilli, Citharichthys spilopterus, Paralichthys lethostigma, Achirus lineatus, Brevoortia patronus, Cynoscion nebulosus, Prionotus sp., Lagodon rhomboides, Symphurus sp. and Gobionellus sp.

Probably more species of fish will be added to each of the above categories as analysis of the catches continues. It is interesting to note that approximately 35 percent of the fish collected are euryhaline. In addition to information on seasonal abundance and spatial distribution, size-frequency data have been compiled for the more abundant series.

The white shrimp (Penaeus setiferus) and brown shrimp (Penaeus aztecus) constitute the major part of the shrimp population while the grass shrimp (Palaemonetes pugio) comprise a small fraction. Of the 3,024 shrimp collected 64 percent were white shrimp; 28 percent were brown shrimp and 7 percent were grass shrimp. Pink shrimp (Penaeus duorarum) were absent from the collections. About 50 percent of the white shrimp were found in sub-area 3 while sub-areas 1 and 2 had 36 percent and 14 percent respectively. The brown shrimp were more evenly distributed; 40 percent in sub-area 2, 32 percent in sub-area 1, and 28 percent in sub-area 3. When the white and brown shrimp are combined, the percentage contribution of each sub-area was as follows: sub-area 1 - 35 percent; sub-area 2 - 22 percent; and sub-area 3 - 43 percent. The white shrimp showed one peak of abundance in October; very few were taken in December 1959 and only two were taken between January 13 and March 9, 1960 in the three sub-areas. The brown shrimp, on the other hand, showed two peaks of abundance, one in November 1959 and the other in May 1960.

Two species of crab are common in the collections, the blue crab, (Callinectes sapidus) and the mud crab (Rhithropanopeus harrisii). The former is by far the more abundant. A total of 2,082 blue crabs were caught and their distribution by sub-areas was as follows: sub-area 1 - 56 percent, sub-area 2 - 24 percent, and sub-area 3 - 20 percent. Despite considerable fluctuations in abundance between samples, there was no clear-cut seasonal periodicity in the crab population. Their catchability does, however, appear to be related to the short-term changes in local salinity. Growth studies based on carapace-width are now being undertaken for each sex separately.

Emphasis has been placed on four common species of mollusks: the oyster (Crassostrea virginica), the mussel (Brachidontes recurvus) and the clams (Rangia cuneata and Mulinia lateralis). Other species identified in the collections were the gastropods: Littorina irrorata, Littoridina sphinctostoma, Nassarius vibex; and the pelecypods: Congeria leucophaeta, Martesia smithi, Spisula solidissima and many others. Despite their tolerance to salinity variation, some mollusks showed preferences for certain environmental conditions. For instance, C. virginica and B. recurvus were taken exclusively in sub-area 3, while R. cuneata was taken only in sub-areas 1 and 2. Mulinia lateralis was found in all three sub-areas with the greatest abundance in sub-area 1.

The zooplankton was rich in variety and showed one pronounced peak in abundance throughout the area in April. The copepod, Acartia tonsa, was the dominant species but ctenophores, coelenterates, polychaetes, and crustacean larvae were also common during the spring. Foraminiferans, chaetognaths, cladocerans, euphausians, mysids, ostracods, heteropods, appendicularians, fish eggs, and larvae occurred spasmodically. However, 24-hour series of oxygen measurements undertaken by Dr. Odum and his colleagues from the University of Texas and further "light and dark bottle" experiments have confirmed our earlier conclusion that the water mass is surprisingly low in primary production.

In addition to the biological investigations, the hydrological work has proceeded according to schedule. Continuous or daily observations have been made at the Hopedale base and regular visits at intervals of 7 to 10 days have been made to the sub-stations scattered over the project area. As previously, the routine measurements at each station have included temperature, salinity, turbidity, pH, oxygen content and total phosphorus. Direct current measurements have been made at selected stations and changes in flow have been measured over 24-hour periods and correlated with prevailing wind. Plotting the depth profiles of the waterways with the Raytheon D 119 has also been continued. Meteorological data have been obtained from recording instruments at the Hopedale Laboratory and by extraction from the local "Weather Maps." Water-level traces have been provided by the Corps of Engineers from their tide gauges at Hopedale and Shell Beach.

SPECIAL REPORTS

Gross Comparison of First Nauplii of Three Penaeid Shrimps

William C. Renfro

Studies of abundance and distribution of commercial and related shrimps during their larval and post-larval development require positive identification of all species taken in systematic collections. Where several overlap in occurrence, the problem of separating them becomes acute since all appear very similar at corresponding stages of early development.

Unfortunately, penaeid larvae and post-larvae have been the subject of very little descriptive and comparative investigation. Such work is therefore being given considerable attention along with studies of larval shrimp abundance and distribution in the Galveston area where at least 10 penaeid species may be expected to occur. To date, all pertinent material has been secured by hatching eggs spawned in the laboratory by ripe female shrimp shortly following their capture.

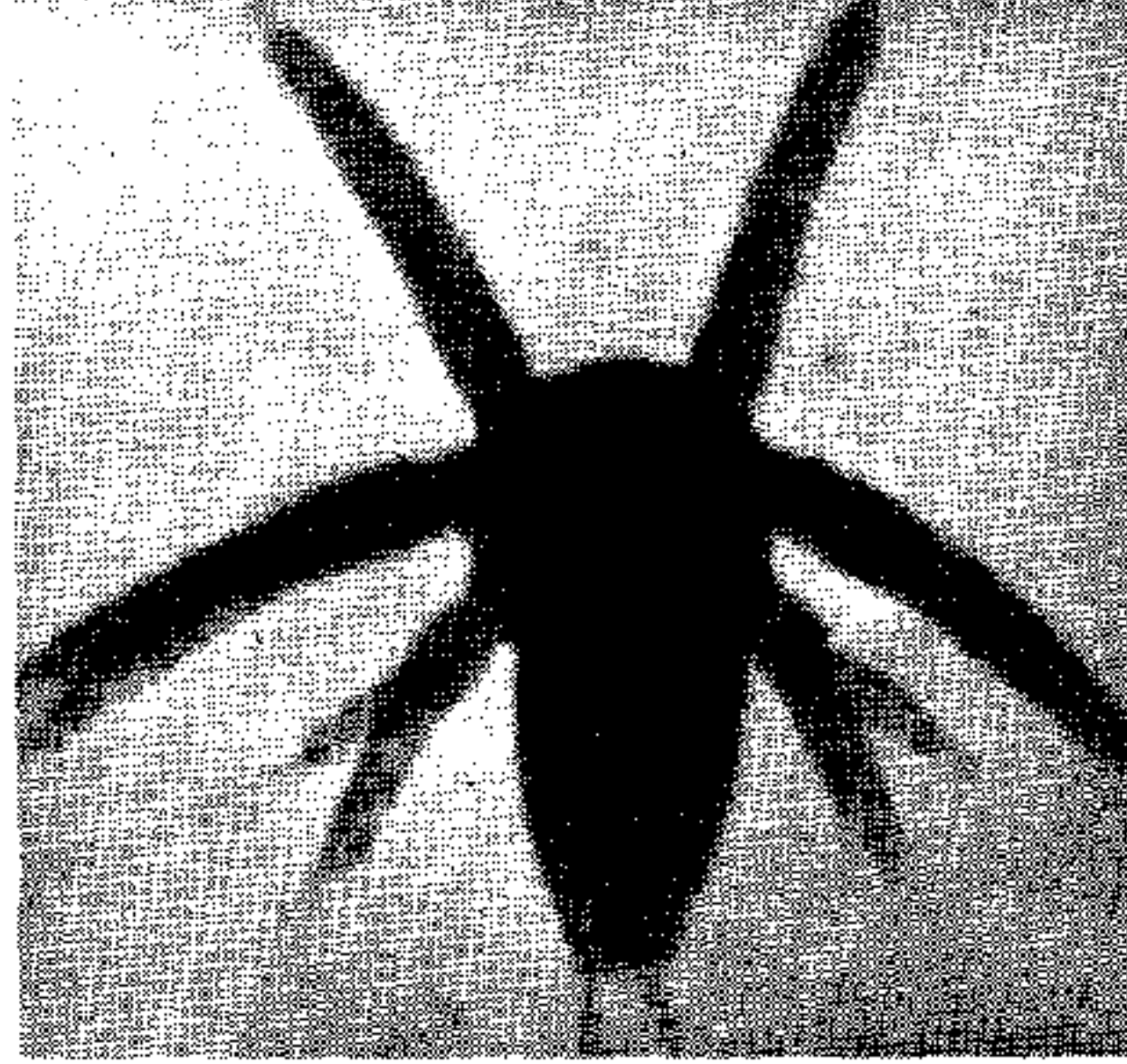
Comparative photomicrographs of the first nauplii of three common penaeid species - the pink shrimp, Penaeus duorarum; brown shrimp, P. aztecus; and seabob, Xiphopenaeus krøyeri - are shown. The pink shrimp specimen was obtained from the University of Miami where descriptive studies of this species were conducted under contract. Those of the brown shrimp and seabob were hatched at the Galveston Laboratory from eggs of known parentage.

As would be expected, the three species are very similar at this stage, each having pyriform bodies, a pair of posterior furcal spines, a small anterior ocellus, a small spine inserted posteriorly on the dorsal mid-line, and three pairs of appendages. The first appendage on either side (first antenna) is finger-shaped and, except for the seabob, bears five setae plus a spike-like spine at its distal end. The seabob Nauplius I differs from the other two in not only having a sixth seta on the antero-ventral surface of its first antennae but also in being distinctly hump-backed in lateral aspect. The second and third pairs of appendages (second antennae and mandibles, respectively) in all three species are very similar in shape and setation. Color differences noted in living specimens disappear after preservation in formalin solution.

Differences in size between the seabob and the two Penaeus species are obvious in the photographs. However, these organisms are small, and such features become apparent only when Nauplii I of several species are available for comparison. Except for some rather subjective features, e. g., the more slender body and appendages in P. duorarum, brown and pink shrimp are almost impossible to separate at this stage.



Penaeus aztecus



Penaeus duorarum



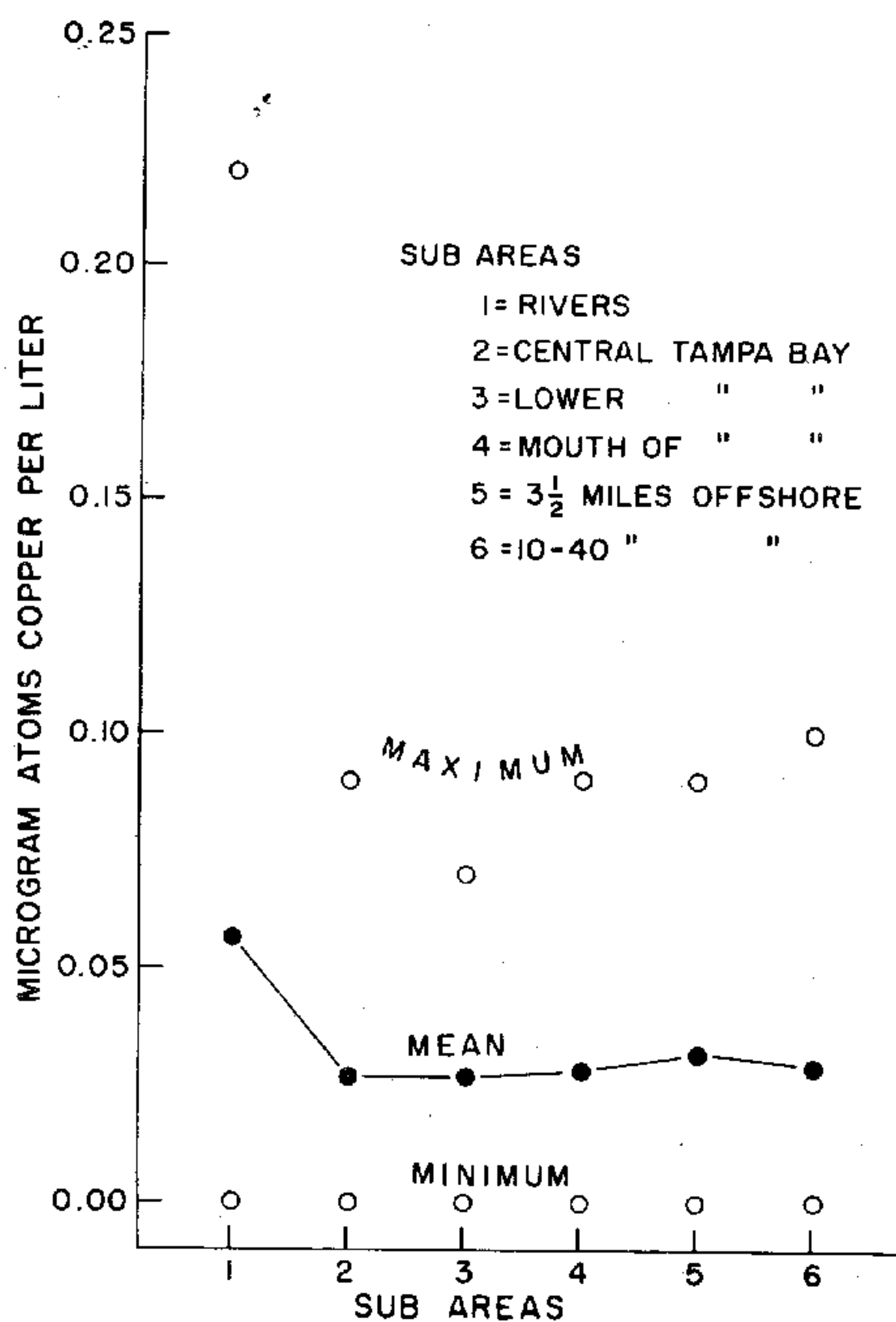
Xiphopenaeus krøyeri

Approximately 70X.

Copper in Tampa Bay and Adjacent Neritic and River Waters

Alexander Dragovich

Laboratory experiments of William B. Wilson have shown that the minimum dissolved copper lethal to Gymnodinium breve (using cultures of lethal concentrations) is about 0.5 microgram atoms per liter (0.03 ppm.). The high toxicity of low concentrations of copper suggested that this element might possibly be a limiting factor in the growth of G. breve in natural waters. From 1955 until October 1958 water samples for copper analyses were collected from the Florida Keys, north to Tarpon Springs. (These data are fragmentary and spread over a large area.) Recent samples from Tampa Bay, tributary streams, and adjacent neritic waters up to 40 miles offshore provide more continuous data and encompass a smaller area.



The maximum copper concentrations were observed in the rivers and varied from 0.00 to 0.22 µg.at./l. with an average of 0.06 µg.at./l. The copper concentrations in Tampa Bay and adjacent neritic waters varied from 0.00 to 0.10 µg.at./l. with an average of 0.03 µg.at./l. The frequency distribution showed that in 64 percent of the samples, copper varied from 0.02 to 0.03 µg.at./l.; in 25 percent from 0.04 to 0.09 µg.at./l.; in 11 percent from 0.00 to 0.01 µg.at./l.; and in 0.2 percent of the samples the copper concentrations were 0.10 µg.at./l. Excluding rivers, the maximum copper values were observed at 10 miles offshore during the red tide outbreak of October 1959. From central Tampa Bay to 40 miles offshore the mean copper concentrations varied slightly and irregularly. Copper concentrations in 87 percent of the samples were below the copper value of 0.003 ppm. or 0.05 µg.at./l. which was reported for sea water by Goldberg in 1957.

Copper has shown no seasonal variation as observed in the English Channel or in San Juan Channel, Washington. The occurrence of monthly peaks was irregular and different in each section of the investigation area.

If we accept 0.5 µg.at./l. of copper as the minimum lethal value to G. breve and 0.03 µg.at./l. (or even the maximal value of 0.10 µg.at./l.) as the value representative of the entire investigation area, the data suggest that the natural levels of copper in Tampa Bay and adjacent neritic waters are not immediately toxic to G. breve.

Brown Shrimp Movements

Anthony Inglis

To investigate the movements of brown shrimp, Penaeus aztecus, in Galveston Bay, 24,338 shrimp marked with biological stains were released in Clear Lake from May 18 through May 22, 1959. Last year's annual report describes techniques employed. Following the last release of stained shrimp on May 22, the upper Galveston Bay area and Clear Creek watershed were deluged with rainfall of 2 to 3 inches in 12 hours. As a result, little or no bait shrimp-ing was carried on during the first 2 days following the final release. Thereafter, weather conditions returned to normal and bait-shrimp fishing rapidly increased throughout the bay area, reaching a peak in July and August.

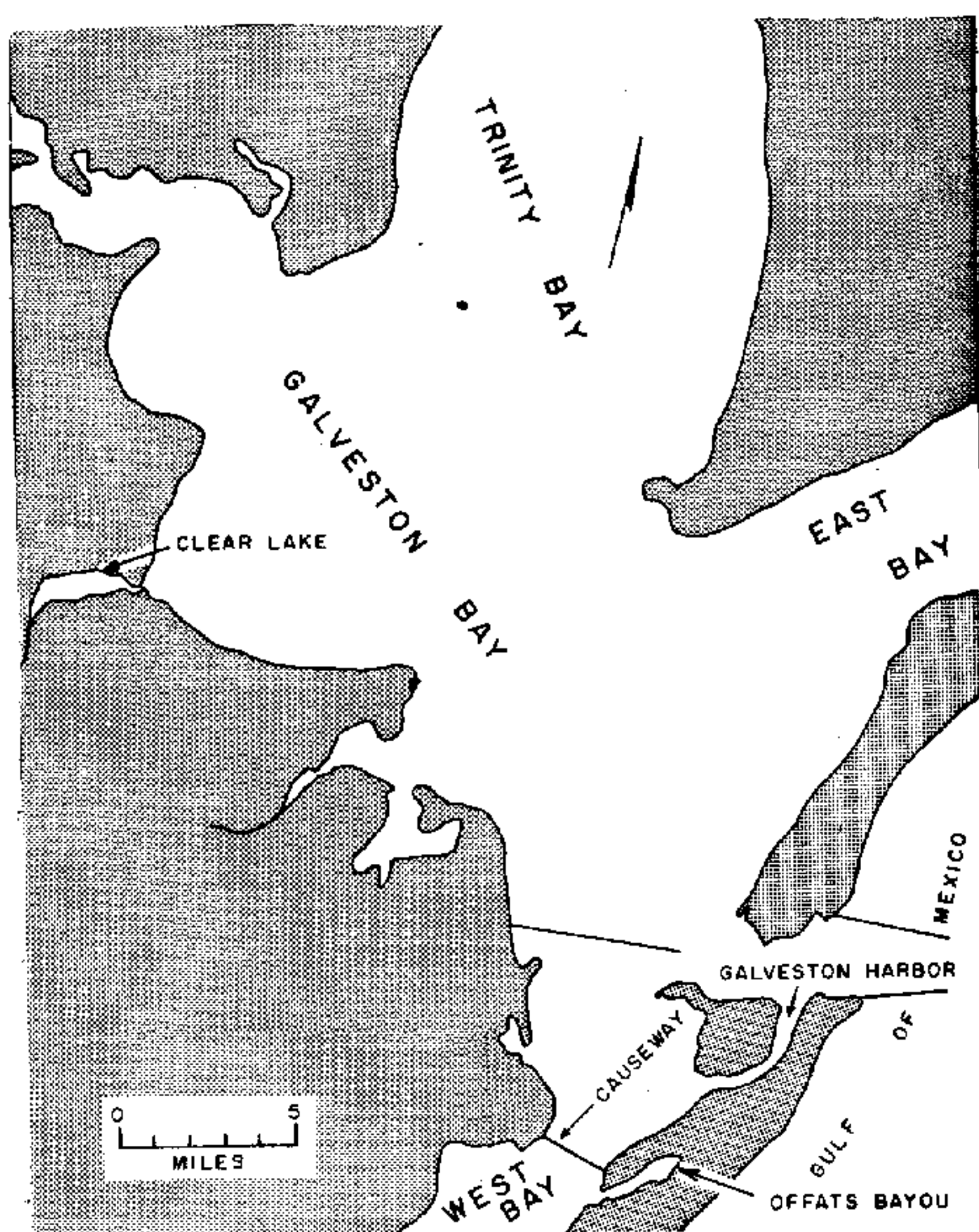


Chart of the Galveston Bay area.

A total of 328 stained shrimp was recovered over a period of 71 days from May 22 through August 1, amounting to a 1.3 percent recovery. About 99.5 percent of the recoveries were made in the first 30 days after release and the remainder in the following 1.5 months. Slightly more than 78 percent of the recoveries came from the area of release (Clear Lake and the Seabrook Channel immediately off the mouth of Clear Lake to Beacon No. 4 -- a distance of 2.5 miles). Almost 5 percent were taken north of the release area, in upper Galveston Bay and Trinity Bay, while 16 percent were taken south of the release site, including part of upper Galveston Bay and all of the lower bay. Almost 1 percent was taken in Gulf waters south and southwest of Galveston. The data are summarized according to area of recapture by 10-day periods.

The directions of movements based on total recoveries are shown diagrammatically. During the first 10-day period there appeared to be a rapid movement of shrimp southward to the vicinity of Galveston Harbor. This could partly be due to the flushing effect of the heavy rainfall, mentioned above, resulting in strong outflowing currents in the Clear Lake and upper bay areas. By the end of the first period 52 percent of the recoveries had been made, of which slightly more than 6 percent were from outside of Clear Lake. During this period six unverified recoveries were reported from the vicinity of

Galveston Harbor as well as one from west of the Galveston causeway, a distance of 27 miles from the release site. Unverified recoveries are not included in the tabulations.

Recoveries by areas by 10-day periods

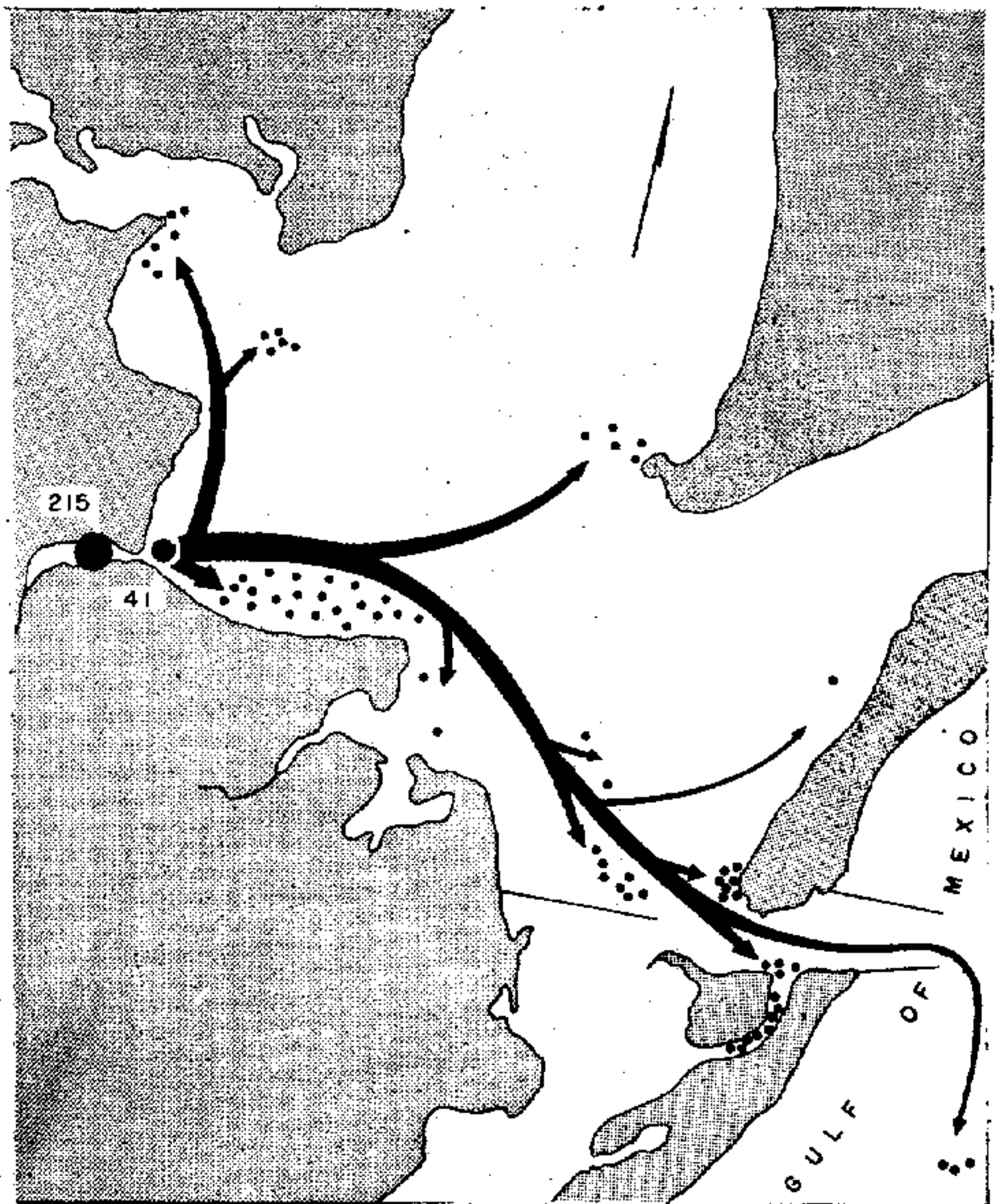
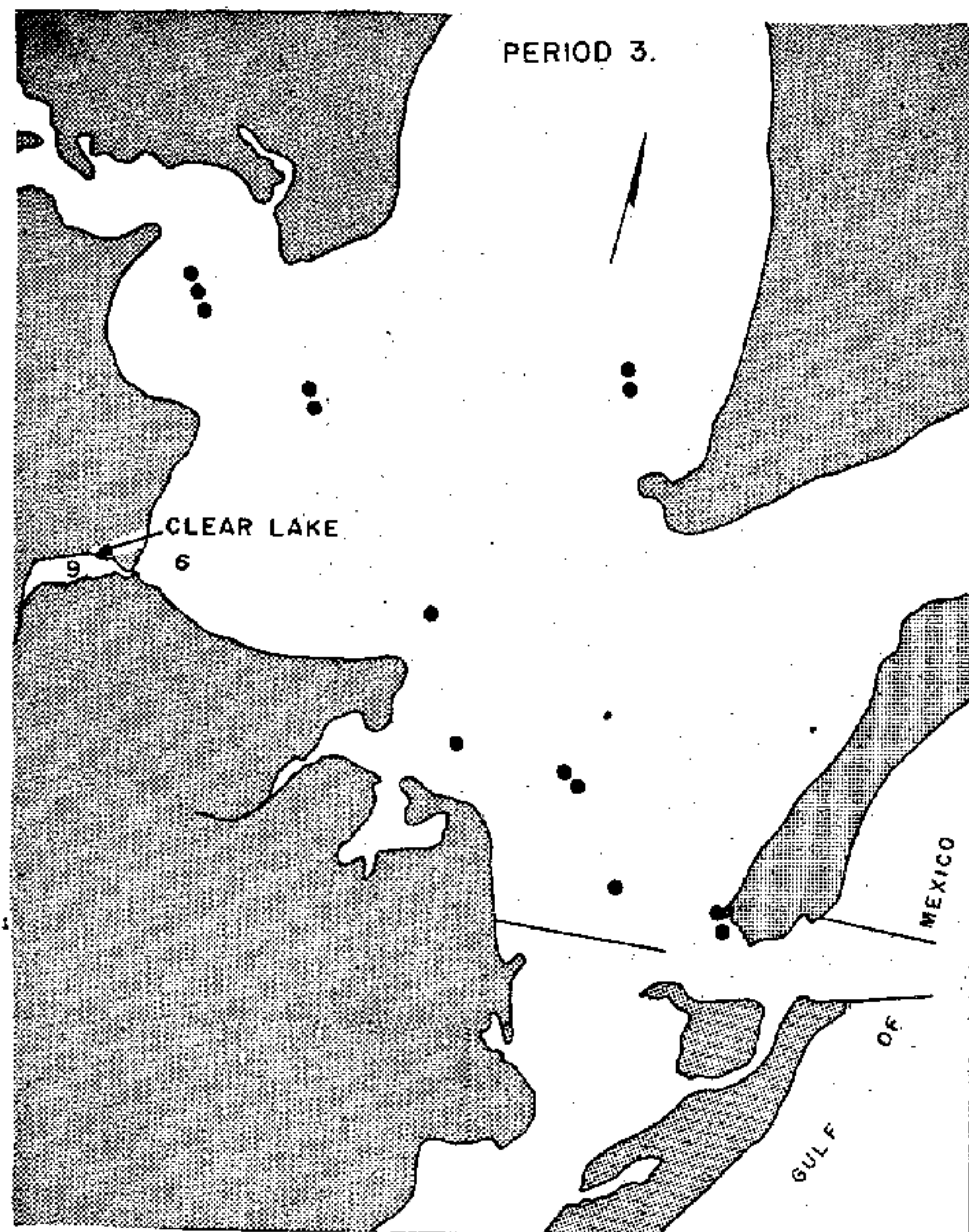
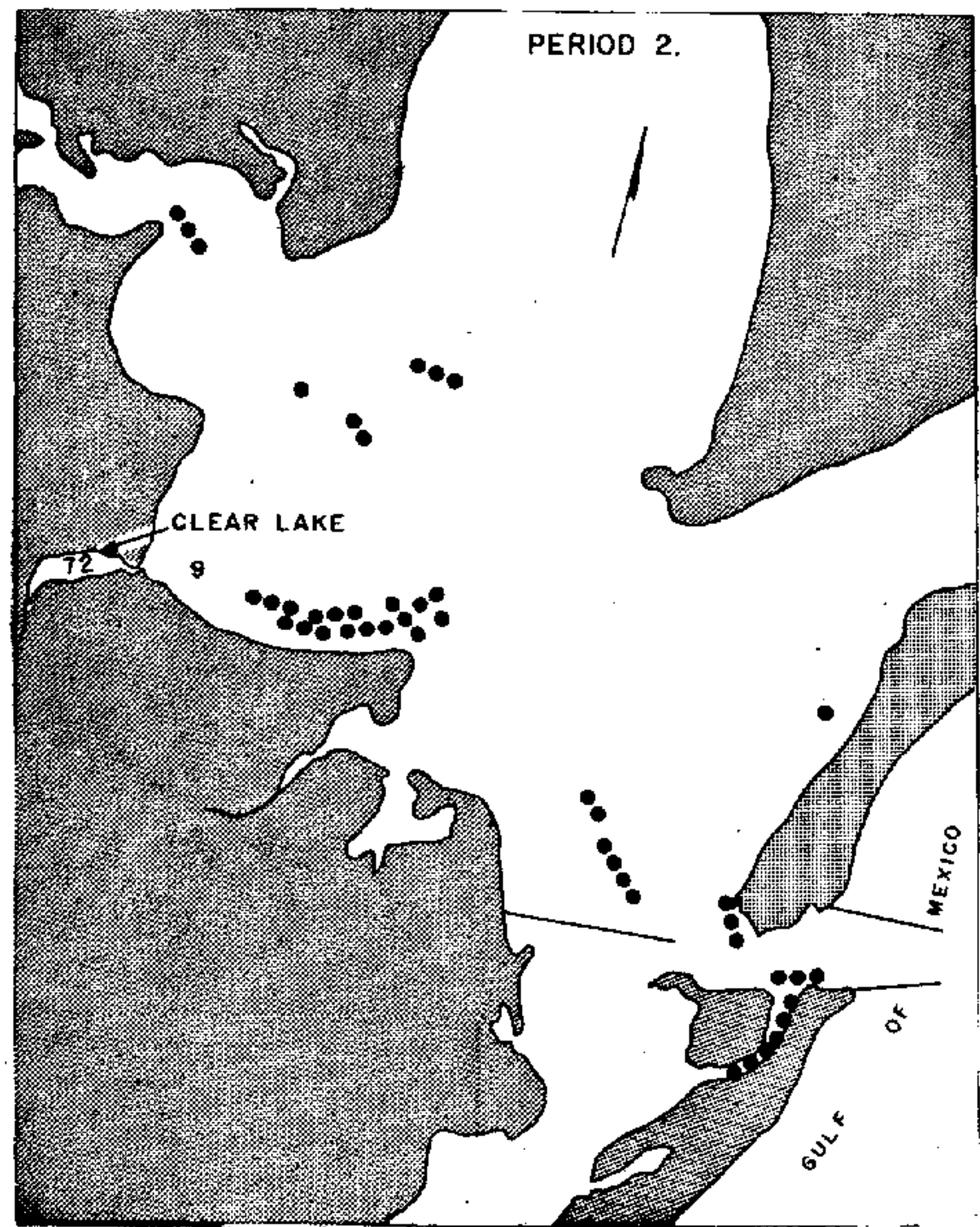
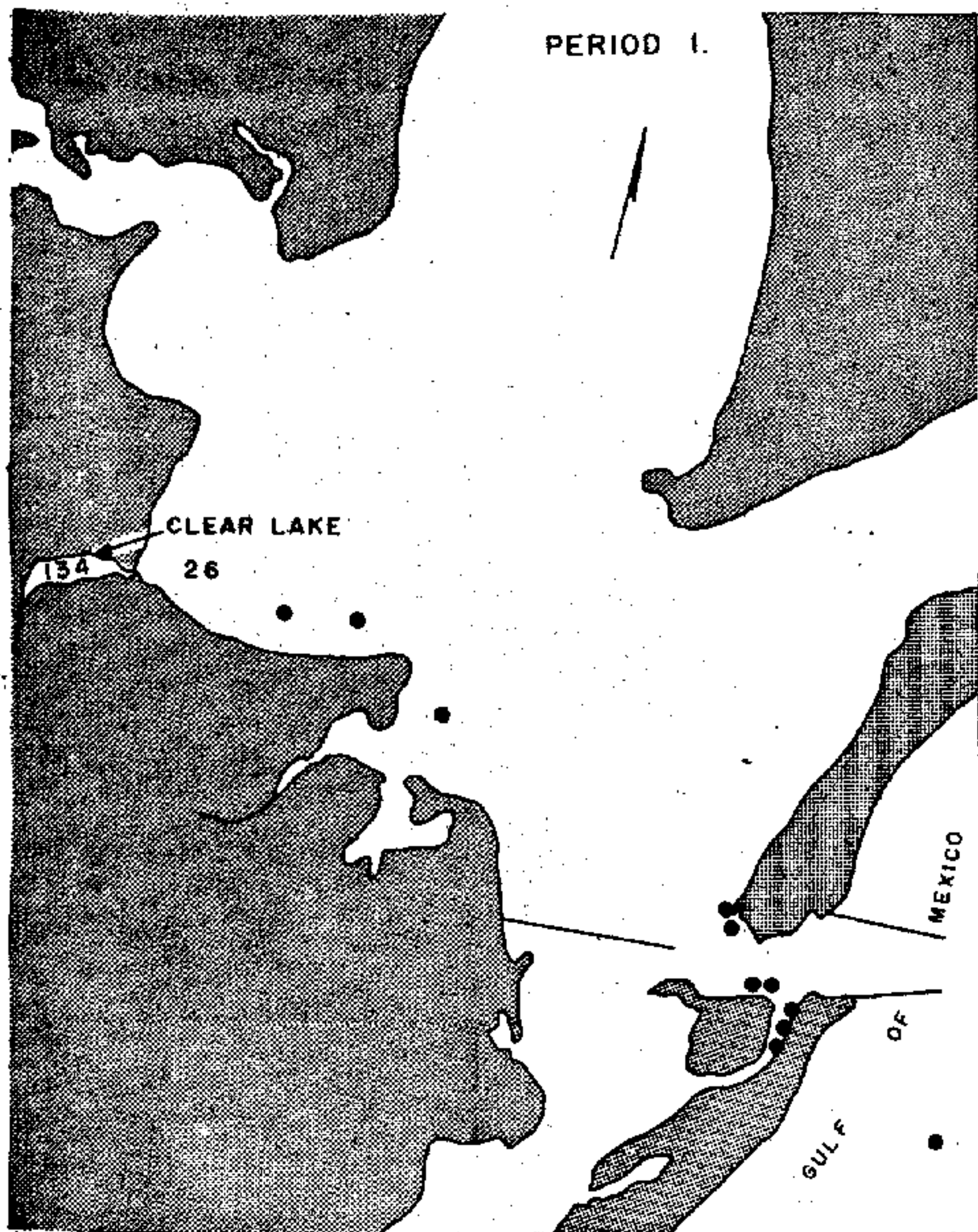
Areas	1st period		2nd period		3rd period		4th-7th period		Totals	
	No.	%	No.	%	No.	%	No.	%	No.	%
Release site	160	48.8	81	24.7	15	4.6	-	-	256	78.1
North of site	-	-	9	2.7	7	2.1	-	-	16	4.8
South of site	10	3.0	36	11.0	7	2.1	-	-	53	16.1
Gulf	1	0.3	-	-	-	-	2	0.6	3	0.9
All areas	171	52.1	126	38.4	29	8.8	2	0.6	328	100

During the second 10-day period slightly more than 38 percent of the recoveries were noted. (nine shrimp were taken north and 36 were taken south of the release area.) Thus, by the end of 20 days, 90 percent of the recoveries had been taken, suggesting a rapid outward movement from Clear Lake with relatively little tendency to linger in the bay. During the third 10-day period, when less than 9 percent of the recoveries were made, the recoveries were evenly distributed between the release area and the rest of the bay. The 14 shrimp recoveries in the bay were, in turn, evenly distributed north and south of the release area. After the third 10-day period, two recoveries were made in the Gulf. They were caught 61 and 71 days after release 125 and 145 miles from the release site.

The complete absence of returns from East and West Bays, in spite of relatively high fishing effort as shown in the table, strongly suggests that brown shrimp from Clear Lake and possibly upper Galveston Bay do not move through these two bays in their Gulfward migration.

Vessel fishing effort in Galveston Bay, May-July 1959

Bay area	May		June		July	
	Hours	Percent	Hours	Percent	Hours	Percent
Release site	75	10.5	232	20.7	342	11.3
North of site	2	0.3	30	2.7	107	3.5
South of site	388	55.0	601	53.5	1,474	48.5
West Bay	141	20.0	126	11.2	500	16.4
East Bay	100	14.2	134	11.9	618	20.3
All areas	706	100.0	1,123	100.0	3,041	100.0

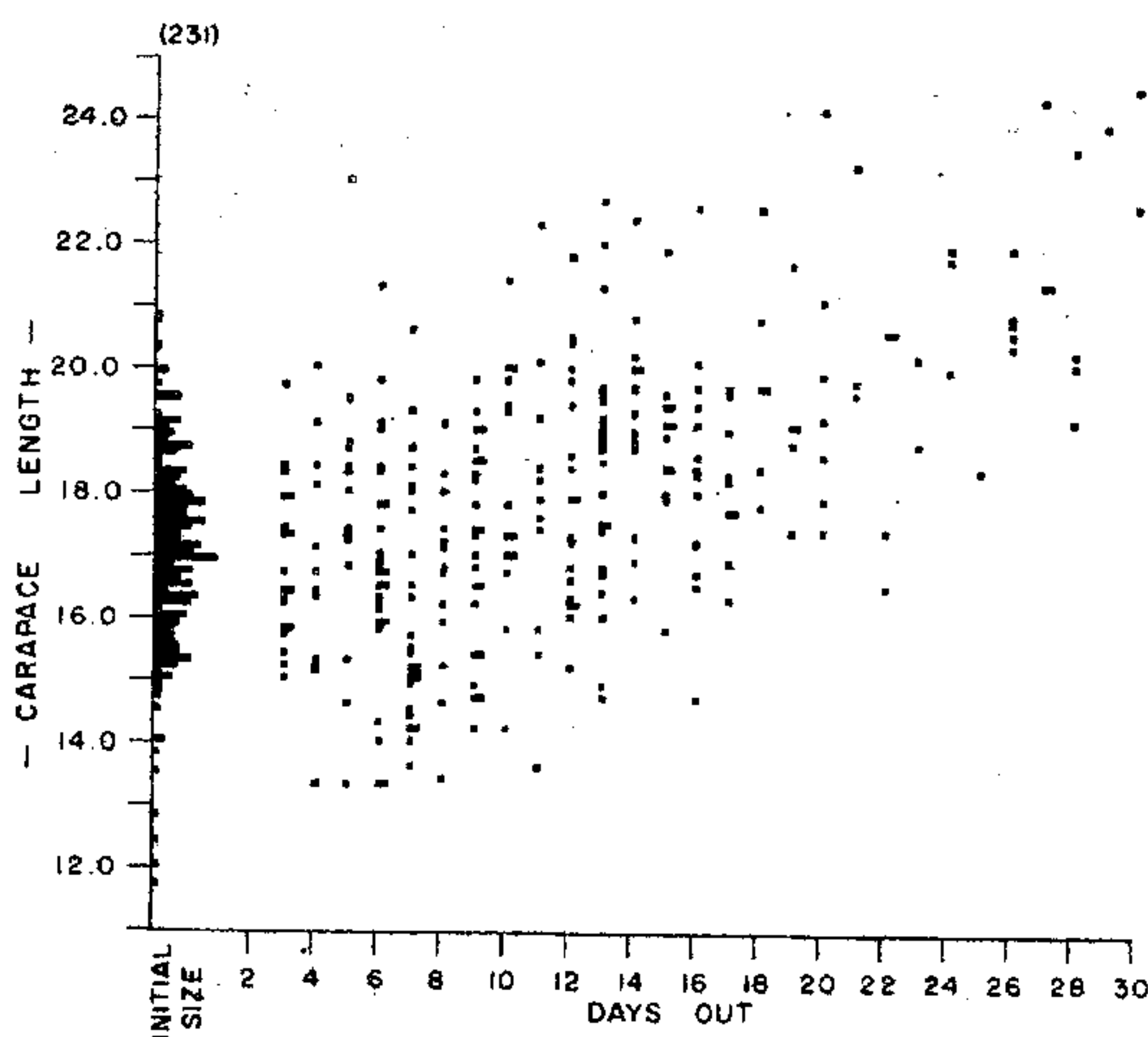


Recoveries of stained brown shrimp released in Clear Lake.

The higher-than-expected returns from the area north of the release site, including lower Trinity Bay, indicate a definite dispersal of brown shrimp from Clear Lake in this direction. The cause of this movement toward the head of the bay system cannot be explained at the present time. Unfortunately, the bays and inshore Gulf waters of Texas were closed to fishing operations by commercial shrimp trawlers (excluding bait fishing) for the 45-day period from June 1 to July 15. Thus, no recoveries would be expected from this area.

The shrimp were sorted prior to staining into two size groups, the smaller (87.8 percent of the releases) were stained with a green dye and the remainder, the larger, with a blue dye. The green shrimp accounted for 90.5 percent of the total recoveries. Most of the blue shrimp recovered were returned within the first 10 days. However, green-stained shrimp were recovered over a longer period of time. This may indicate that the larger size group moved seaward sooner than the smaller.

An indication of growth can be seen in the increasing size of the recoveries with time (shown in the figure below). However, estimates are probably minimal because as shrimp grow larger there is a general movement back to the Gulf.



Sizes of recaptured shrimp in relation to the elapsed time at liberty.

Identification and Distribution of Pink Shrimp Larvae

C. P. Idyll, F. F. Koczy, Albert C. Jones,
M. O. Rinkel and Sheldon Dobkin
University of Miami Marine Laboratory
(Contract No. 14-17-008-113)

Study of the larval history of the pink shrimp, Penaeus duorarum, was begun January 1, 1959. From July 1, 1959 to June 30, 1960, 11 cruises were made to the Dry Tortugas fishing grounds and to Florida Bay to collect shrimp larvae. Four of these cruises were made on oceanographic research vessels to study water currents in the area. In addition, plankton tows were made in the inshore waters of Everglades National Park and in the channels between the Florida Keys. A total of 860 tows was made, and the pink shrimp larvae from 720 of these have been counted and classified according to stage.

The eggs and the larval stages of the pink shrimp have been described and illustrated, and a report on this phase of the research has been submitted to the Bureau of Commercial Fisheries for publication. The first six larval stages were described from specimens reared from eggs. Rearing experiments were successful in raising larvae through the five naupliar stages and into the first protozoal stage. Larvae could not be raised beyond the first protozoa even with the use of antibiotics and various food cultures. The remainder of the stages were described from preserved material collected in plankton tows. This was possible since only one species of the genus Penaeus is known from the Dry Tortugas area. Comparison of the larval stages of P. duorarum with those of the white shrimp, Penaeus setiferus, and with post-larvae of the brown shrimp, Penaeus aztecus, was made and will help workers in areas with more than one species of Penaeus to identify these species collected in their plankton tows.

Systematic sampling of the Tortugas fishing grounds and Florida Bay is being carried out to determine the spawning season and the spawning area of the pink shrimp. The results obtained to date indicate that spawning takes place throughout the year but is most intensive from June through September. Spawning appears to be restricted to offshore waters from about 12 to 25 fathoms. No nauplii or protozoa have been taken in inshore waters of less than 8 fathoms although postlarvae are present at these shallower stations. Five and six rostral spine postlarvae are the youngest stages which have been found in Whitewater Bay estuary. Three and four rostral spine postlarvae are the oldest found on the fishing grounds or in Florida Bay.

In general, the average numbers of pink shrimp larvae taken per successful tow have been small. Intensive spawning, as indicated by larger numbers of larvae, has been found on the northern boundary of the controlled fishing area. Another station, close to the northwest boundary of the fishery, has not been sampled during the summer spawning season but has had moderate numbers of larvae present during the winter.

Diurnal migration is a widespread phenomenon among planktonic organisms. An understanding of diurnal distribution is necessary to develop an accurate sampling system for measures of abundance and mortality rates. It is well known that adult pink shrimp are nocturnal and usually burrow into the bottom during the day. Reactions of the planktonic larvae to light were determined from a comparison of the catches of day and night tows. Few pink shrimp larvae were found in day surface tows, but they were more abundant at night. Mid-depth and bottom tows at night had more nearly equal numbers of larvae as compared with day tows. Postlarvae were generally more abundant than any other stage at the surface in both day and night hauls. Protozoa were more abundant than any other stage in mid-depth and bottom hauls.

The current system in Florida Bay and on the fishing grounds is being studied to determine how shrimp larvae reach the nursery grounds. The main currents in this region are the tidal currents. Consequently, at each current station a minimum of $1\frac{1}{2}$ tidal cycles must be observed to get the component of the permanent current. Current crosses were utilized to follow the paths of a water parcel over a given time period. Their position at various times over the tidal cycle was determined in relation to a fixed navigation aid or an anchored radar reflector. Both surface crosses, two meters below the surface, and bottom crosses, three meters above the bottom, were used. In addition, modified Carruthers meters have been used to measure currents within 6 inches of the bottom.

The data obtained thus far are preliminary because of the scarcity of stations and of seasonal and yearly coverage. The water currents at most stations are a classic example of a tidal ellipse. The total tidal excursion between any two tidal turning points is about 5 miles, which gives a tidal current of a little less than 1 knot in a nearly east-west direction. The permanent currents are generally less than one-tenth knot. Bottom currents are in the same direction as and of lower magnitude than the surface currents.

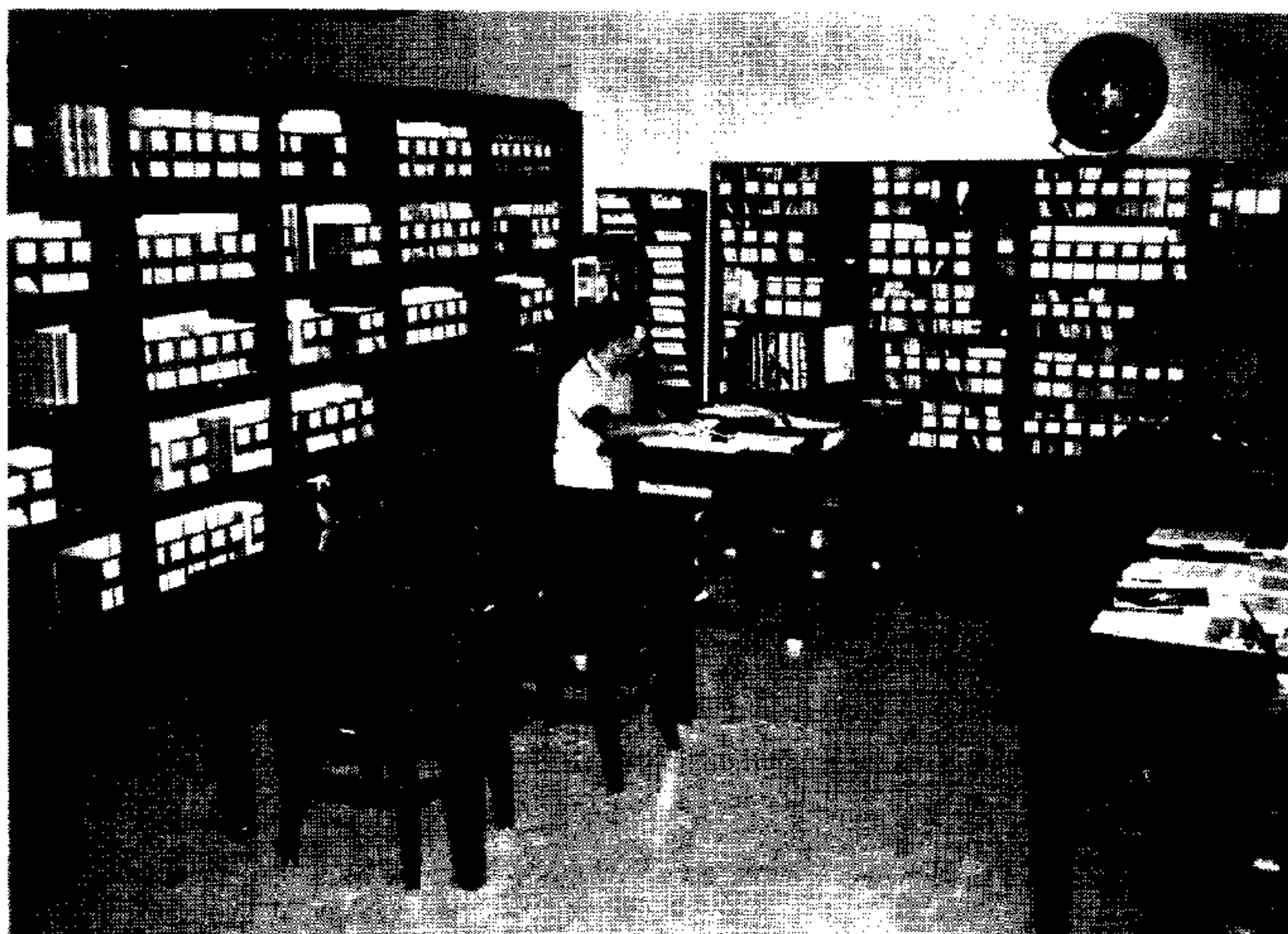
Measurements indicate the existence of a westerly permanent current in this region. Only a few stations had an easterly current. Moreover, their speeds were so small, compared with the overall accuracy of the method, that it would be more appropriate to attribute a zero velocity to these stations. The existing westerly currents cannot transport the larvae from the spawning area towards the shore, a distance of 100 miles in an easterly direction. Even if the current direction were reversed, the distance could only be traveled in about 1,000 hours, or roughly 6 weeks.

All measurements have been carried out under essentially easterly and southeasterly wind conditions. This limits the results to weather of this type, which is the prevailing one throughout the year. During an easterly wave (westerly wind conditions) occurring during winter, the current flow pattern may be reversed.

LIBRARY

Stella Breedlove

With the addition of 1,320 items during the past year, the library collection now totals 6,596 items, including books, journals, magazines, reprints, and reports. There were 262 volumes added to the book collection and 76 volumes added to the microcard collection. During the year approximately 90 government offices and laboratories were contacted for official publications relating to fisheries. Interlibrary loans for the year show a decrease. The unbound material in the library was transferred to Princeton files, providing additional space. Total shelving in the library measures 436 linear feet.



Statistical summary of library collection

	On hand			Additions	On hand
	1957 ^{1/}	1958 ^{1/}	1959	1960	1960
Books	1009	1015	1226	262	1488
Journals	111	187	274	8	282
Journals (unbound)		420	514	177	691
Reprints		983	1284	290	1574
Institutional			1597	428	2025
Other			381	155	536
Total items			5276	1320	6596

^{1/} Inventory not complete.

SEMINARS

Ecological studies of East Lagoon. Ray Wheeler
Effects of salinity on shrimp. John VanDerwalker
Statistical inference via a representative investigation. Joseph H. Kutkuhn
Plankton pigments in East Lagoon. Zoula P. Zein-Eldin
Parasites of fishes. William B. Wilson
Effects of copper ore on the ecology of a lagoon. Kenneth T. Marvin
Anesthesia in fishes. Wm. McFarland, Inst. of Marine Science, U. of Texas
Theories of dinoflagellate aggregation. David V. Aldrich
Plankton pigments in East Lagoon. Zoula Zein-Eldin at Rockport
Herring spawning in southeastern Alaska. Bernard E. Skud
Research activities of the Central Marine Fisheries Institute of India. Sushil
Kumar Banerji, Madras State, India
Methods of enumerating salmon in Alaska. Richard Straty, Bureau of Commer-
cial Fisheries, Juneau, Alaska
The blue crab. Edward Chin
Classification of "estuaries". Anthony Inglis
Gas bubble disease in fishes. William Renfro
General biology and toxicity of dinoflagellates. William B. Wilson at Medical
School, University of Texas.

MEETINGS ATTENDED*

American Institute of Biological Sciences, Penn. State College, Aug. (2)
International Oceanographic Congress, New York, N. Y., Aug. (2)
American Fisheries Society, Clearwater, Fla., Sept. (4)
Gulf States Marine Fisheries Commission, Corpus Christi, Tex., Oct. (1)
Atlantic Estuarine Research Society, Virginia Beach, Va., Oct. (2)
Gulf and Caribbean Fisheries Institute, Nassau, Nov. (1)
Texas Shrimp Association, Corpus Christi, Tex., Jan. (1)
National Cannery Association, Miami Beach, Fla., Jan. (1)
North American Wildlife Conference, Dallas, Tex., Mar. (4)
Gulf States Marine Fisheries Commission, Mobile, Ala., Mar. (1)
Atlantic Estuarine Research Society, New Holland, N. C., May (2)
Southeastern Fisheries Association, Clearwater, Fla., May (1).

*Attendance shown in parentheses.

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*Contract research.

**Cooperative research.

MANUSCRIPTS SUBMITTED FOR PUBLICATION

- Arnold, Edgar L., Jr., Ray S. Wheeler, and Kenneth N. Baxter
Fishes and other biota of East Lagoon, Galveston Island.
- Christmas, J. Y., Gordon Gunter, and Edward C. Whatley
Fishes taken in the Gulf of Mexico menhaden fishery.
- Dobkin, Sheldon
Early developmental stages of the pink shrimp.
- Dragovich, Alexander, John H. Finucane, and Billie Z. May
Red tide organisms and associated oceanographic data, 1957-1959.
- Finucane, John H., and Billie Z. May
Modified Van Dorn water sampler.
- Gunter, Gordon, and J. Y. Christmas
A review of literature on menhaden.
- Gunter, Gordon, and William J. Demoran
Cephalic lateral lines of menhaden.
- Iversen, Edwin S., Andrew E. Jones, and C. P. Idyll
Size distribution of pink shrimp on the Tortugas fishing grounds.
- Marvin, Kenneth T., and Larence M. Lansford
Phosphorus content of some fishes and shrimp in the Gulf of Mexico.
- Marvin, Kenneth T., Larence M. Lansford, Ray S. Wheeler and Ray Proctor
Effects of copper ore on marine organisms.
- Marvin, Kenneth T., Zoula P. Zein-Eldin, Billie Z. May, and Larence M. Lansford
Chemical analyses of marine and estuarine waters.
- Renfro, William C.
Salinity tolerance of fishes in the Aransas River, Texas.
- Skud, Bernard E., and William B. Wilson
Role of estuarine waters in Gulf fisheries.
- Zein-Eldin, Zoula P.
Plankton pigments in East Lagoon, Galveston, Texas.